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MEETING SAN FRANCISCO DROUGHT CONDITIONS[1]

By T. W. Espy[2]

Among my earliest recollections is hearing my father make the remark that a certain person was always just one jump ahead of his creditors. Thirty-five years experience leaves the impression that at least a large part of California is most of the time less than one jump ahead of its water requirements.

We hear from all sides talk of water shortage and dry years and often we hear the older generation say "if we could only have rains such as we used to have." I, for one, give small credence to that remark, but a short study of rainfall records indicates that these old-timers are correct. The United States Weather Bureau publishes an 82-year record of San Francisco rainfall. The first 41 years of this record show an average annual rainfall of over 24 inches, while the last 41 years show an average of barely 20 inches per year.

The San Francisco rainfall record is perhaps the best obtainable index of the earlier runoff in the Bay area. Taking the rule-of-thumb runoff as proportional to the square of the rainfall, the runoff during the period 1849 to 1890 would be nearly 50 per cent greater than the runoff since 1890. Is not this the explanation why San Francisco, with long runoff records, now finds the average productivity of its watersheds much less than the older records would indicate?

[1] Presented before the California Section meeting, October 30, 1931.

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Although the cycle must sometime return to rains such as the older generation speaks of, it is now necessary to neglect older records and make productivity estimates on the lesser rainfall of the more recent years.

In the face of this 41-year period of subnormal rainfall, San Francisco's water requirements prior to the present time were well taken care of. There was no year prior to 1924 that the water in San Francisco's reservoirs at the end of each dry season was not equal to practically a year's consumption. The first really serious year of threatened shortage was 1924. The situation in this year was relieved by drawing heavily on the underground supply west of the town of Pleasanton in Livermore Valley. The Spring Valley Water Company acquired rights to this underground supply in the year 1898, but prior to 1924 had used practically nothing except the artesian flow. The years 1927 and 1928 each produced runoff, so that at the end of each dry season there remained more than one year's supply in surface storage. The Pleasanton underground supply also recovered to practically an artesian flow. The spring of 1929 produced little runoff and at the end of April there was one year's supply in surface storage. Again, we drew heavily on the Pleasanton wells. Nineteen-thirty was another dry year and at the end of April of that year there was nine months' supply in surface storage. Again we drew on Pleasanton wells at the rate of 15 m.g.d. and Sunset wells in the sand hills of the southwestern section of San Francisco. In the latter field, at the urgent request of M. M. O'Shaughnessy, City Engineer of San Francisco, the Spring Valley Water Company started well development just before San Francisco purchased the water system in March, 1930.

Even with these two underground supplies it was apparent that at the end of 1930 there would be very little water in our surface storage, and the underground sources would be much depleted.

If the rainy season of 1930–31 were similar to 1924, we would require during all of 1931, 47 m.g.d. from some source other than the surface catchment of the San Francisco Water Department system. If the year were similar to the average of the previous 12 years, we would require 7 m.g.d. for some outside source. There appeared to be three alternatives:

1. Turn Hetch Hetchy water down the San Joaquin river, pick it up near Tracy, and pump it through a temporary pipe line over Altamont Pass and into the Water Department's system in Alameda County.

2. Connect the Water Department's pipe system on the east side of San Francisco Bay with the East Bay Municipal Utility District's water supply.

3. Pump salt water from the Pacific Ocean into the distributing pipes as a protection against fire, and then let the milk delivery boy furnish drinking water along with the milk delivery.

EAST BAY DISTRICT CONNECTION

In September, 1930, the San Francisco Board of Supervisors, appreciating the gravity of the situation, appointed a committee headed by the present Mayor Angelo J. Rossi (then Supervisor Rossi) to investigate and make a report on the water situation. As a result of the labors of this committee, and the very courteous assistance of the officials of the East Bay District, an agreement for San Francisco to procure 20 m.g.d. from the district was consummated in October, 1930. To transport this water a pumping plant at San Lorenzo and 13 miles of pipe line between the District's system at San Lorenzo and the San Francisco pipes at Newark were needed. This construction was authorized October 14. Bids were received on November 5, and on November 26, 1930, a contract was signed with the Western Pipe and Steel Company for the fabrication and installation of 6 miles of 36-inch diameter and 7 miles of 44-inch diameter welded steel pipe with welded bell and spigot field joints. The right of way for this pipe was procured under condemnation proceedings on December 23, 1930, and the pipe installation started immediately thereafter. It was completed on February 21, 1931—108 days after award of the contract. The East Bay Municipal Utility District expended about $50,000 in pipe line and pumping plant changes to accomodate their system to deliver the required 20 m.g.d.

A few years ago, before the Hetch Hetchy 42-inch diameter submarine pipe across San Francisco Bay at Dumbarton Strait was constructed, a consulting civil engineer of San Francisco requested a description of the methods used by the Spring Valley Water Company in placing their submarine pipes across the bay. This engineer quoted quite a well-known consulting engineer as saying that from all he could learn the Spring Valley Water Company must have just thrown their submarine pipe overboard.

The temporary 13 miles San Lorenzo-Newark pipe might be described as being just thrown overboard. It lies on the surface of the ground, with no anchor or braces at angles or any place else. Of

course, it is underground at all road crossings, and on redwood blocking where it crosses salt marshes. Otherwise, one end is fastened to the discharge end of the pumps and the other end 13 miles away is fastened to the Hetch Hetchy Bay Division pipe line. None of the 13 miles of pipe line has yet tried to run away. There has been a pressure on it of as much as 150 pounds. The pipe is welded throughout, coated with a hot dip of California asphaltum, and wrapped with Pabco soil proof pipe covering. It lies out in the sun, but the wrapping has not sagged, the asphalt has not run, nor has the pipe run away, although it has moved slightly when empty.

The Utility District's water is received at the ground surface at San Lorenzo and delivered through pipe lines and Pulgas tunnel into Crystal Springs reservoir, 30 miles away.

The lift of 260 feet plus the pipe friction is made at two pumping plants: one, the Pulgas pumps on the west side of San Francisco Bay, has three centrifugal pumps operated by three 500 H. P. electric motors; the second, the San Lorenzo pumping plant, was built by the Water Department forces at the same time and as a part of the emergency connection. The original installation at San Lorenzo pumping plant consisted of three single stage centrifugal pumps powered by three 250 H.P. synchronous motors.

The surface catchment last spring and the catchment in 1924 were identical and we had made an installation for only 20 m.g.d. from the Utility District. Additional Sunset wells and deeper wells and deeper pumping equipment at Pleasanton were constructed.

The Utility District again generously consented to furnish the water at the maximum rate possible without endangering their own supply.

Equipment bringing the total pumping capacity to over 40 m.g.d. was installed at San Lorenzo. This installation now consists of four centrifugal pumps with 250 H.P. synchronous motors and three centrifugal pumps with 700 H.P. synchronous motors. These pumps, together with the three 500 H.P. units at Pulgas, are arranged for use in several combinations. They will deliver the maximum amount of water under operating conditions when the four 250 H.P. pumps are discharging into the suction side of the three 700 H.P. units.

Procuring in excess of 20 m.g.d. from the Utility District necessitated increasing the facilities of the District to deliver the additional water to the San Lorenzo pumping plant. These increases in the

District's facilities were paid for by San Francisco and embraced a number of small construction changes as well as some 5 miles of 30-inch diameter pipe line.

A tentative date for completion of the Utility District's 30-inch pipe line was set as July 1 and a date two weeks earlier for installation of the pumping equipment. The District's pipe line was completed two weeks ahead of schedule and the Water Department pump installation was one week later. Based on this experience, the equipment should have been ordered in the following manner: first, the gate valves, then pipe fittings, motors, and pumps last.

Practically all the construction costs in connection with procuring water from the East Bay Municipal Utility District were paid from Hetch Hetchy bond funds. The emergency construction on Pleasanton wells, the Sunset wells, and the operating costs were paid from the income of the San Francisco Water Department.

EMERGENCY HETCH HETCHY SUPPLY

Last March the San Francisco Board of Supervisors adopted an emergency water supply program, sponsored by Mayor Angelo J. Rossi, under which the Hetch Hetchy San Joaquin pipe line, now under construction, is to be completed by next July. Also, as a part of this program the Supervisors have directed that plans be prepared and a contract let for completing by that date a temporary pipe line to bypass Hetch Hetchy water around the uncompleted coast range tunnels. These two pipe lines together with the installation of a siphon across the Tuolumne river at Red Mountain Bar will allow the delivery of 45 million gallons per day of Hetch Hetchy water into San Francisco.

The Water Department's supply will also be increased by completion next month of the Upper Alameda Creek Diversion Dam and Tunnel, which will divert the runoff from some 33 square miles of watershed into Calaveras reservoir of the Water Department system; adding an average of 13 million gallons per day to the present developed supply.

San Francisco's water consumption, furnished by the Water Department, this year will average 53 million gallons per day, which is about 80 gallons per capita. For a number of years past the increase in consumption has averaged 3 per cent per year. The above consumption figures do not include some 10 million gallons

of water per day which is supplied from private wells within the city limits.

Since July 1 our supply has been 30 million gallons per day from the East Bay Municipal Utility District, 13 from the Pleasanton wells, 6 from the Sunset wells, 2 from the Sunol Valley natural gravel filter beds, and the remainder from surface storage. At the end of this year, we expect to have 80 days' supply in surface storage. If the next rainy season is like the past one we expect, with the continued generous assistance of our neighbors, to keep San Francisco supplied until the emergency pipe line can bring water from the Hetch Hetchy system next July.

THE FILTRATION PLANT AND PUMPING STATION AT LOCKPORT, NEW YORK[1]

By J. F. Laboon[2]

Lockport, after many years of effort which involved internal differences in the various administrations as to the engineering details which should be employed to give the City pure filtered water, finally voted a bond issue of $550,000 in November, 1926 for the purpose of installing new pumping machinery at the low service pumping station located on the Niagara River at North Tonawanda, and the construction of an eight million gallon filtration plant, a six million gallon reinforced concrete reservoir and a high service pumping station in Lockport. Several Alderman refused to authorize, by their vote, aldermanic action in the matter of issuing the bonds because some of the Alderman thought it would be best to build another pipe line from the Niagara River to Lockport, rather than a filtration plant. The refusal of these Alderman to take official action prevented the necessary majority for the issuing of the bonds. All of this consumed more than two years. In the meantime (June, 1928) the plans and specifications had been completed, bids taken, and contracts awarded pending the issue of bonds. By virtue of legal entanglements, contacts for the construction work were not signed until June, 1929, when construction work was begun.

The filtration plant and pumping station were put into operation in February, 1931 and, by a favorable turn of human affairs, some of the very Aldermen who opposed the project for years, now became proud fathers of the completed construction program.

CONDITIONS BEFORE FILTRATION

The City of Lockport takes its water supply from the Niagara River by means of an intake pier and intake line, whence the water is pumped to Lockport by a pumping station located on the banks of the river at North Tonawanda through a 30-inch steel line, 14 miles long, constructed about 25 years ago.

[1] Presented before the New York Section meeting, September 22, 1931.

[2] Consulting Engineer, The J. N. Chester Engineers, Pittsburgh, Pa.

The North Tonawanda Station contained (3) motor driven centrifugal pumps, each designed to deliver 5 m.g.d., but later reconstructed to increase their capacity to approximately 6.5 m.g.d., each. These pumps were installed more than 20 years ago.

The raw water was chlorinated at the North Tonawanda Station and delivered in this form at Lockport. Chlorination was the only safeguard the City had to keep from serious epidemics due to the highly polluted water of the Niagara River.

At Lockport, after the water had been pumped 14 miles, the only storage serving as a balance wheel for the pumping machinery and as a reserve for fire protection, was a steel standpipe 25 feet in diameter and 126 feet high, which holds about 450,000 gallons at the overflow point. In case of a shut-down at the North Tonawanda Station due to interruption of electrical power or in the case of a rupture of the 30-inch steel force main, as actually happened during the war when a portion of the line was blown up, the City had but two hours before the standpipe would run dry. The absence of controlling devices at the standpipe, and the remoteness of the North Tonawanda Station, made it difficult to keep the standpipe from overflowing, if its capacity and the pressure in the city were to be maintained at a maximum, as the result of which it is estimated that one million gallons per day of the total water pumped to the City went into the sewers by way of the overflow. This was borne out by a pitometer survey made several years ago.

For the year 1927, when the studies for the capacities of the filtration plant were made, the average daily pumpage at the North Tonawanda Station, according to Venturi meter readings, was 6.4 million gallons in prosperous times, or 280 gallons per capita; in 1928 it was 7 million gallons, or 305 gallons per capita; in 1929, 8.5 million gallons, or 370 gallons per capita; in 1930 the average approached 9 million gallons and for the months of March, April, May and June of this year the average was approximately 8 million gallons, in times of dire depression. The consumption on individual days has been over 11 million gallons. The actual consumption for the years 1927, 1928, 1929 and 1930 was about 1 million gallons less than the pumpage, or 5.4 m.g.d. in 1927, since overflow at the standpipe has been estimated as being about 1 m.g.d. This is in contrast to the 8 m.g.d. capacity of the filtration plant as actually designed. The revenue has not increased proportionately to the increase in water consumption for these years.

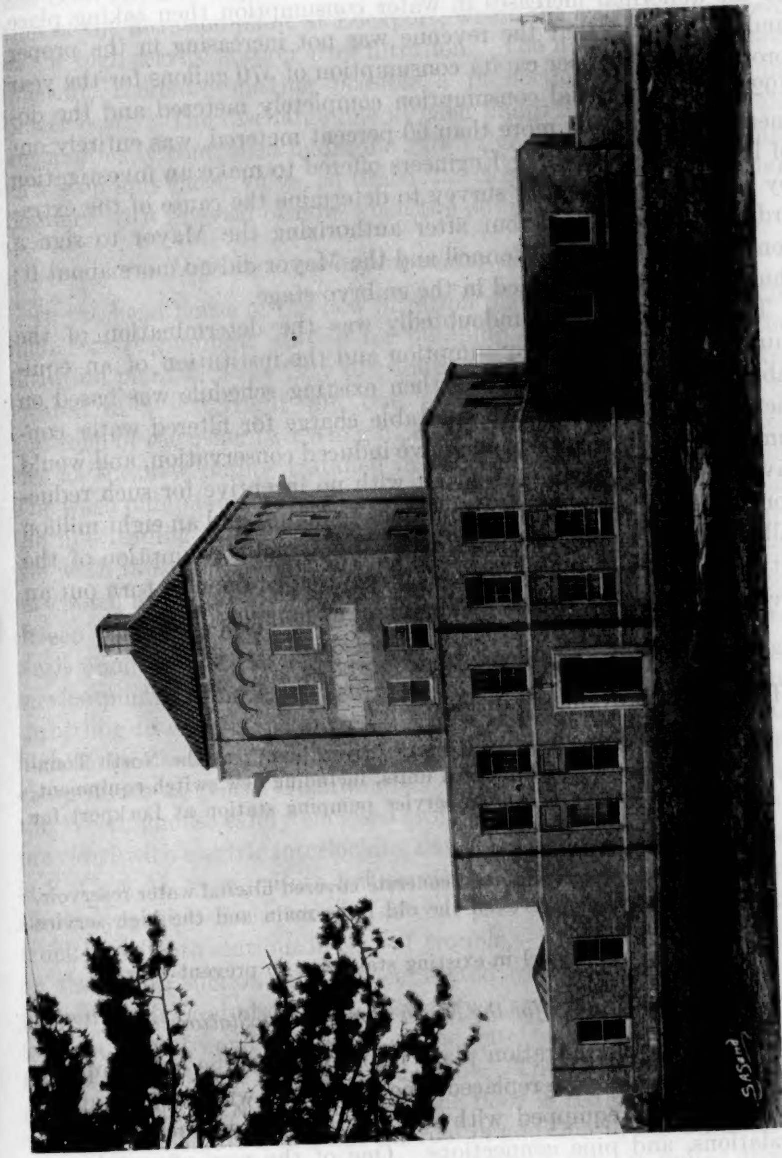

FIG. 1. FILTRATION PLANT. SETTLING BASINS ON RIGHT AND RESERVOIR ON LEFT

The attention of the City fathers was directed, by the Engineers, to the abnormal increases in water consumption then taking place and to the fact that the revenue was not increasing in the proper proportion. The per capita consumption of 370 gallons for the year 1929, with industrial consumption completely metered and the domestic consumption more than 60 percent metered, was entirely out of line. The Consulting Engineers offered to make an investigation by means of a pitometer survey to determine the cause of the extraordinary consumption, but after authorizing the Mayor to sign a contract, the Common Council and the Mayor did no more about it; thus the investigation died in the embryo stage.

The proper solution undoubtedly was the determination of the cause of the abnormal consumption and the institution of an equitable rate schedule, since the then existing schedule was based on the sale of raw water. An equitable charge for filtered water consumed by the industries would have induced conservation, and would have eliminated wastefulness, but with no incentive for such reductions the water consumption continues to mount and an eight million gallon filtration plant, designed when the actual consumption of the City was approximately 5.4 m.g.d. is now called upon to turn out an average of 8 m.g.d., with a maximum of as much as 11 m.g.d.

NEW IMPROVEMENTS

The new improvements include:

1. Replacing of the 3 existing motor driven pumps at the North Tonawanda Station with modern units, including new switch equipment.
2. The construction of a high service pumping station at Lockport for pumping filtered water.
3. An 8 m.g.d. filtration plant.
4. A 6 million gallon reinforced concrete covered filtered water reservoir.
5. Cross connections between the old force main and the high service pumping station.
6. Control of water level in existing standpipe to prevent overflow.

New Pumps for the North Tonawanda Station

Upon placing the filtration plant into operation the old pumps at North Tonawanda were replaced, one at a time, with new pumping units completely equipped with new switching equipment, wiring, foundations, and pipe connections. One of the new pumps has a capacity of 5, and each of the other two, 8 m.g.d. The pumping head

has been reduced approximately one-half by virtue of the installation of the filtration plant at Lockport, where the water is repumped at the high service station after filtration. The new pumps are more efficient, therefore making possible a proportionate reduction in power costs. The discharge line at each pump is equipped with an automatically controlled hydraulic gate valve designed to serve both as a stop and check valve, so timed in closing as to prevent water hammer with reversal of flow when the power is cut off suddenly.

High service pumping station at Lockport

In the head house of the new filtration plant is located a complete high service pumping station for pumping filtered water from the filtration plant into the City distribution system. Three pumps are located in a watertight pit, one pump having a capacity of 5, and each of the other two, 8 m.g.d., corresponding to the same capacities as the new pumps installed in the North Tonawanda Station. The wash pump is also installed in this station, taking its suction from the line leading to the filtered water reservoir and discharging into the wash tank located on the top floor of the head house. An auxiliary wash line connects with the filtered water force main. A motor driven vacuum pump serves to prime the main pumping units and wash pump. The valves on the discharge lines of each of the high service pumps are solenoid controlled hydraulics to permit of hand throttling to govern the output. The gate valves on the individual high service suction lines are equipped similarly to those on the discharge lines at North Tonawanda. The switching equipment is of the Westinghouse safety enclosed switchboard removable truck type, provided with electric interlocking devices. The starting equipment is E. C. & M. type. Both low service and high service stations are similarly equipped electrically, so that it is possible to have a spare truck serve both stations in case of trouble. The hydraulic controls on the pump suction lines are connected with an emergency water pressure unit, and also with a manually operated pressure pump for automatic and hand regulation of the gate valves in case of power failure or sticking of the hydraulic piston. The walls of the pump pit are lined with glazed brick, while the floor is red Master Builders. Two large skylights located in the roof in addition to the windows at the balcony supply natural light to the pit. A five ton motor driven crane spans the entire pit.

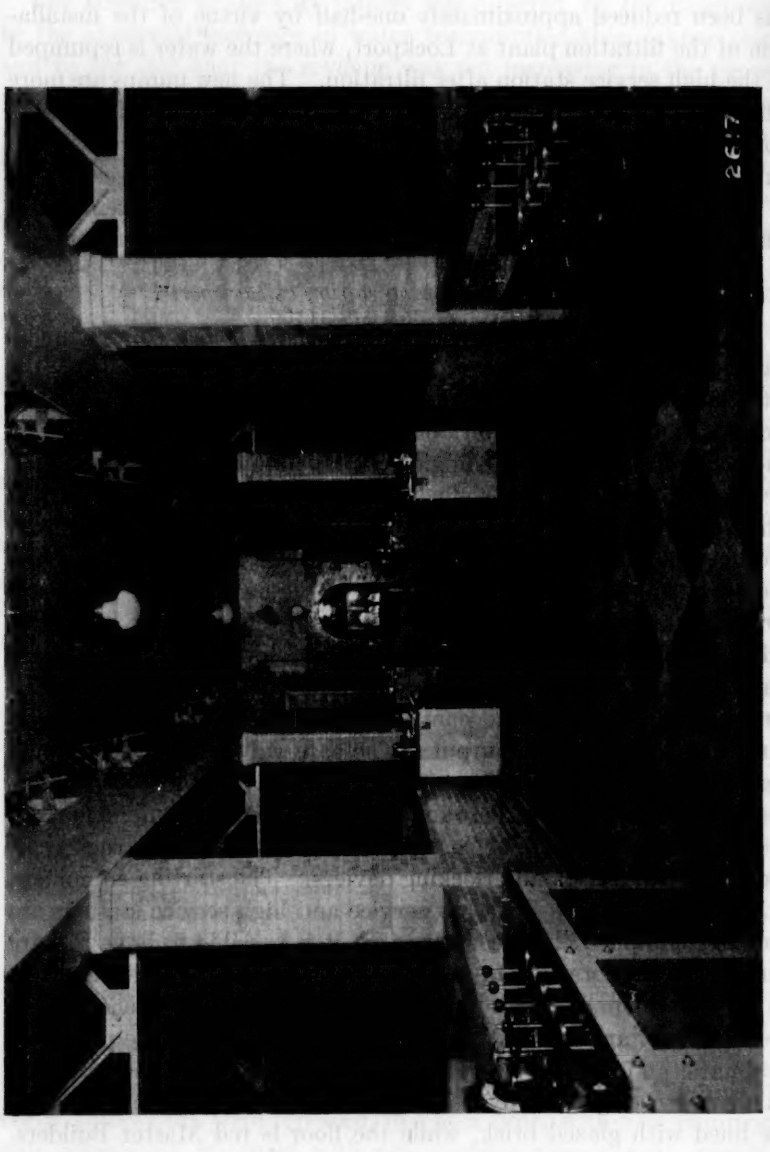

Fig. 2. Filter Operating Floor at Night

Filtration plant

The filtration plant consists of a head house in which are located the high service pumping station, lobby, master control, superintendent's office, chemical machine room, chemical storage room, sand washer and sand storage bin, chlorine room, boiler room, toilet and locker rooms, laboratory and wash tank; a filter house with eight filter units; and a mixing building with two steel mixing tanks fully equipped. The main building consists of four stories in addition to the pump pit and basement. An electric elevator serves to convey the chemicals from the unloading platform to the storage room on the second floor. The building is of brick and concrete throughout with structural steel framing. The trimming is Indiana limestone. The floors of the lobby, offices, balcony, and filter operating room, together with the tops of the filters, are finished in terrazzo. The filters are equipped with concrete false bottoms. A clear well under each row of filters on either side of the pipe gallery collects the individual filter effluents whence a filtered water main cross-connecting both clear wells conveys the filtered water to the 6 million gallon clear water storage reservoir. The filters are subject to master control, centralized in the lobby of the head house. The wash water system is capable of producing a 36-inch per minute rise in the filters to combat mud balls and algae.

A system of unit heaters was provided for heating the basement of the head house, the high service pump pit, the pipe gallery, the filter room and the mixing building.

The two steel mixing tanks give a detention of between 10 and 11 minutes at 8 m.g.d. The raw water entering the mixing tanks by means of the 14 mile force main is controlled by an automatic, hydraulically operated gate valve which is actuated by the level of the water in the mixing tanks so as to prevent overflow throughout the filtration plant. The three dry feed machines are of the International automatic proportional feed type.

The two settling basins are covered and are of reinforced concrete throughout with a detention capacity of 4 hours at the rate of 8 m.g.d. Both inlet and outlet distributing walls are of the perforated type, subject to adjustment by plugging up the perforations.

The filter operating tables are of green and pink marble, equipped with the latest type International Filter Company control apparatus. A large indicating wash water gauge is located on the wall above the

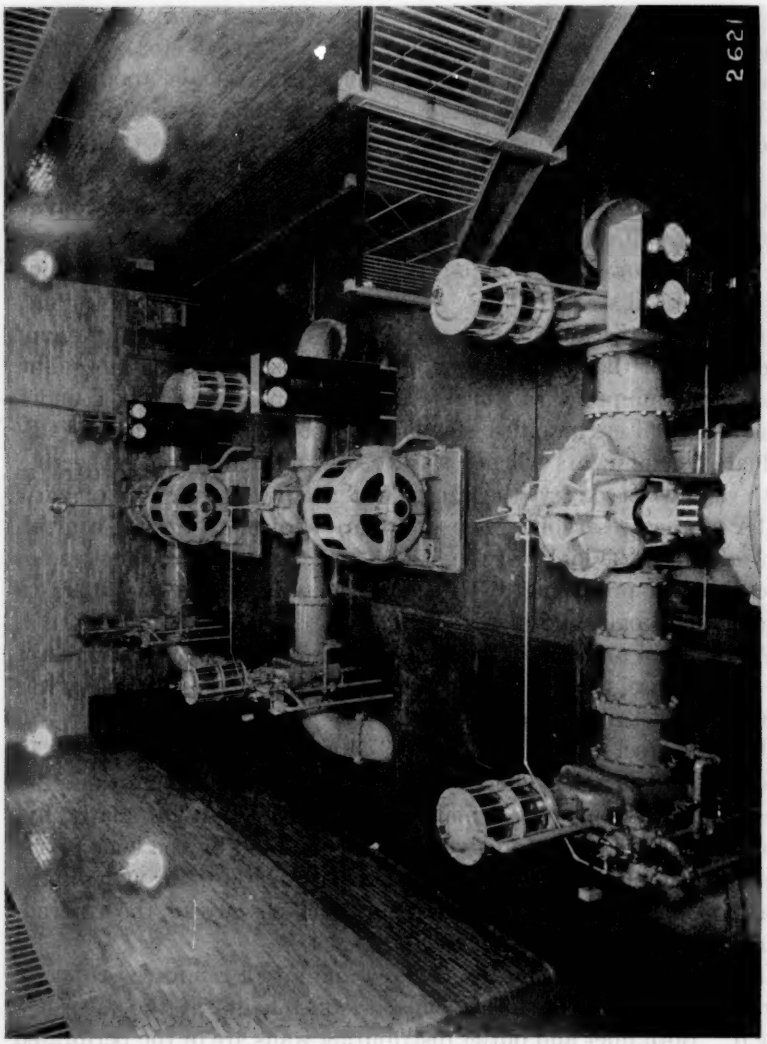

FIG. 3. HIGH SERVICE PUMP ROOM

entrance to the filter room, where it is readily observed by the operators.

Clear water reservoir

The clear water reservoir is of reinforced concrete throughout with a roof covered over with earth and embanked on all sides. It has a capacity of 6 million gallons. The reservoir is baffled through the center to provide for circulation and thus prevent stagnation. The filtered water main from the filters enters the reservoir on one side of the baffle by means of a manifold header, while a similar manifold outlet serves as a pump suction line on the other side of the baffle. It is the intent of the designing Engineers that this reservoir shall serve as a balancing reservoir between the low service and the high service pumping stations and the filtration plant in order that uniform rates of pumpage and filtration may be employed and maintained, and thus permit most convenient and economical operation.

Cross connections

A cross connection was installed between the existing steel force main on Summit Street and the high service pumping station at the filtration plant. This connection was so designed as to permit the testing out and tuning up of the filtration plant without endangering the continued supply of water to the City. A new gate valve in the 30-inch steel force main line was to be removed and the opening blanked off after the filtration plant was established in service, so as to avoid any danger of contamination of the filtered water supply by leakage from the raw water line. This gate valve and cross connection, however, were left in service at the instance of the Common Council of the City, although duly protested by the Engineers.

Control of water level in existing standpipe

The water level, in the existing standpipe, where so much wastage was experienced in the past from substantial overflows, is equipped with a high water alarm apparatus, which rings a large gong located in the filtration plant when the water level in the standpipe reaches a certain predetermined level below the overflow point.

COSTS

The cost of the complete work, according to the final estimates, is as follows:

North Tonawanda low service station	$32,000
Lockport high service station	74,500
Filtration plant	227,000
Clear water reservoir	157,477*
Cross connections	10,000
Grand Total	$500,977

* This included an extra of $9,695 for extra concrete and wood piling required for the foundations, as the result of encountering quicksand.

OPERATION

The filtration plant was placed into operation in February, 1931. Nothing unusual has developed in the operation since that time. However, some concern was felt from the fact that filter runs were shortened materially during the month of May when algae in great quantities made their first appearance in the raw water. Some of the difficulties could have been reduced by operating the plant at a uniform rate, as was intended by the use of the clear water reservoir as a balancing medium between the rates of filtration and consumption.

During the months of March, April, May and June the coagulants were added in variable quantities from 0.37, as a minimum, to 0.62 grain per gallon, as a maximum monthly average. The highest rate of coagulant used on any day was 1.2 grains per gallon, when the turbidity was recorded as being 260 p.p.m. The maximum average length of filter runs was 25 hours in March, while the minimum was 12 hours in May, when the algae flow was at its height. The wash water averaged 2.2 in March and 6.7 percent in May. The filters are washed usually when the loss of head has reached 9.5 feet. To date no trouble has been experienced with filters becoming "air bound." Filter runs have extended as long as 140 hours. During this period of operation the expansion method of sand washing was not used, but inasmuch as this has been provided for in the wash water facilities, whereby a rise of 36 inches per minute may be obtained, it is expected that more attention will be paid to this detail in future operation.

The automatic control valves on the individual pump discharge lines have operated most satisfactorily at the North Tonawanda Sta-

tion where they have prevented reversal of flow entirely when the power was cut off suddenly without causing any water hammer, but in the Lockport station, where the discharge line is much shorter and the time of closing, therefore, must be correspondingly less, adjustments had to be made for reducing the time of closing to 5 seconds which has been accomplished with most satisfactory results.

AMMONIATION IN THE NEWARK WATER SUPPLY

By Julius F. D. Bauermann[1]

Prior to the recent completion of the North Jersey District Water Supply Commission's Wanaque Project, the City of Newark (population 445,000) together with several adjacent communities—Belleville, Bloomfield and Nutley, with an additional population of some 85,000—were served entirely by the Pequannock watershed. Today, various areas in these towns still receive their entire water supply from this source, other areas being fed from the Wanaque system, while still other sections use water from both sources.

The Pequannock watershed collection system consists of four collection reservoirs and several large ponds with a combined storage capacity of 10 billion gallons, all feeding into the Pequannock River which, in turn, conveys the water a distance of 5 to 8 miles to the intake of the gravity supply line. From the intake—or intakes—two paralleling gravity pipe lines, one of 48-inch, the other 42-inch diameter, carry the water a further distance of some 18 miles to the first distribution reservoir at Cedar Grove. (At Great Notch, 17 miles down the line, and for the remaining 1 mile, numerous "cross overs" have been arranged to secure thorough mixing of the Water in both pipe lines). Some 25 percent of the daily average consumption of 60,000,000 gallons is furnished to consumers at higher elevations and is necessarily drawn from the two pipe lines before reaching Cedar Grove Reservoir. The remaining 75 percent, some 45,000,000 gallons per day, is fed into this latter reservoir, which has a storage capacity of approximately 10 days normal consumption. From Cedar Grove the supply is distributed to the communities previously mentioned. Two balancing reservoirs, one in Belleville and one in South Orange, together with the necessary pipe lines, complete the distribution system. The combined storage capacity of the three distribution reservoirs is approximately 700,000,000 gallons or, in terms of average daily consumption, about 10 days' supply in the

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Cedar Grove Reservoir, one day's supply at South Orange and two day's supply in the Belleville Reservoir.

The intakes of the two gravity lines previously mentioned are some 6500 feet apart—No. 1, pipe line of 48-inch diameter taking

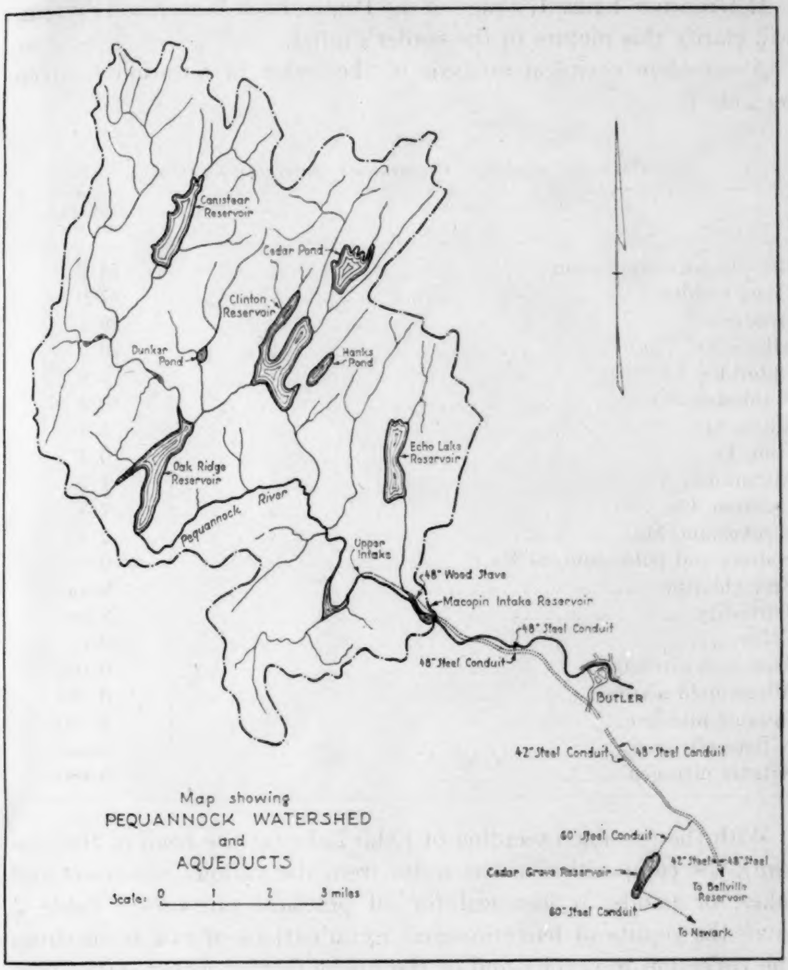


FIG. 1

water directly from the Pequannock, No. 2, the 42-inch diameter pipe taking water from a small (32 million gallon) reservoir fed by the Pequannock. This reservoir affords some slight additional sedi-

mentation for the water flowing through the No. 2 pipe line. For the distance between the upper and lower of these intakes, No. 1 consists of a wood stave pipe, but from the lower intake to the Cedar Grove Reservoir, steel pipe is used throughout both lines.

Reference to figure 1, a map of the Pequannock Watershed System, will clarify this picture in the reader's mind.

A complete chemical analysis of the water in question is given in table 1.

TABLE 1

Chemical analysis, Pequannock watershed supply

	PARTS PER MILLION
Residue on evaporation	54.2
Fixed residue	37.0
Hardness	29.1
Alkalinity	20.9
Chlorides, Cl	2.9
Sulphates, SO_4	10.6
Silica, Si	5.1
Iron, Fe	0.3
Aluminum, Al	1.1
Calcium, Ca	7.3
Magnesium, Mg	2.8
Sodium and potassium, as Na	0.8
Free chlorine	None
Turbidity	None
Color	20.0
Ammonia nitrogen	0.009
Albuminoid nitrogen	0.083
Organic nitrogen	0.200
Nitrite nitrogen	None
Nitrate nitrogen	0.060

With the possible exception of Echo Lake (at the head of the system), the composition of the water from the various revervoirs and lakes, or ponds, is identical for all practical purposes. Table 2 gives the results of bacteriological examinations of raw water from the collection reservoirs and of the unchlorinated water at the pipe line intakes.

The occasional variations in taste and odor of water from the different reservoirs are shown in table 3. This table is based on the results of weekly "hot and cold" tests for taste and odor.

Included in this same table 3 are standard unit counts of both

amorphous matter and microörganisms as a possible indication of taste and odor causes and variations.

Throughout the watershed system algae growths are both prolific and extensive. Noticeable seasonal variations in species have been observed and recorded as shown in table 4. The predominating seasonal species are underscored.

As will be seen from the data in tables 3 and 4, it has been possible to classify seasonal odors and tastes and to correlate these with the presence of definite algae species.

Normally chlorination of both pipe lines at the intakes, with two Wallace and Tiernan Vacuum Chlorinators, is practiced, chlorine

TABLE 2

Bacteriological quality—average for indicated period—raw water

SOURCE	SEPTEMBER TO NOVEMBER, 1930		DECEMBER TO FEBRUARY, 1931		MARCH TO MAY, 1931		JUNE TO AUGUST, 1931	
	Nutrient agar plate count	B. coli, lact. bile (Hale index)	Nutrient agar plate count	B. coli, lact. bile (Hale index)	Nutrient agar plate count	B. coli, lact. bile (Hale index)	Nutrient agar plate count	B. coli, lact. bile (Hale index)
Macopin Intake	117	2.5	11	0.7	34	0.6	570	13
Echo Lake Brook	75	18.6	16	0	22	0.23	488	15.6
Kanouse Brook	785	16.8	66	1.0	36	1.2	635	19
Clinton Brook	95	11.9	34	0.4	25	0.53	636	18.8
Oak Ridge Brook	200	10.5	68	0.08	22	0.23	304	3.5

being applied at the rate of 1.5 to 1.6 p.p.m. during the summer and at the somewhat reduced rate of 1.1 to 1.2 p.p.m. during the winter. At a point 1500 feet beyond the point of chlorine application residuals of 0.5 in summer and 0.3 to 0.4 p.p.m. in winter are found with standard ortho-tolidin test. Seventeen miles further down the line, at Great Notch, these residuals have diminished to 0.07 to 0.08 in summer and 0.03 to 0.04 in winter. Chlorine residuals are purposely kept lower in winter than in summer, because the bacterial quality of the water is much better and because higher residuals in cold water have been found to cause chlorinous tastes. As is to be expected, with normal chlorination as above practiced, no chlorine residuals can be detected at the outlet of the Cedar Grove Reservoir (5 to 10 days following chlorine application).

TABLE 3

Physical and microscopic quality—for indicated periods—of raw water

SOURCE	SEPTEMBER TO NOVEMBER, 1930				DECEMBER TO FEBRUARY, 1931				MARCH TO MAY, 1931				JUNE TO AUGUST, 1931			
	Odor		Amorphous matter per cubic centimeter standard units	Microörganisms per cubic centimeter standard units	Odor		Amorphous matter per cubic centimeter standard units	Microörganisms per cubic centimeter standard units	Odor		Amorphous matter per cubic centimeter standard units	Microörganisms per cubic centimeter standard units	Odor		Amorphous matter per cubic centimeter standard units	Microörganisms per cubic centimeter standard units
	Cold	Hot			Cold	Hot			Cold	Hot			Cold	Hot		
Macopin Intake	1 E., G.	2 G., E.	121	64	0	1 G., E.	166	78	1 E., M.	2 E., G.	147	386	1 G., E.	2 G., E.	211	42
Echo Lake Brook	1 M., F.	3 M., F.	269	1,096	2 F., G.	3 G., F.	188	642	1 Ger.	2 G. E. and Ger.	603	2,362	1 M.	2 G., E.	286	129
Kanouse Brook	1 M., F.	2 M., G.	95	18	0	1 E.	179	13	0	2 G., E.	141	29	1 G., F.	2 G., E.	152	10
Clinton Brook	1 F., M.	2 G., F.	214	11	0	2 G., F.	358	12	0	2 G., E.	136	39	1 F.	2 G., E.	162	25
Oak Ridge Brook	1 G., E.	2 G., E.	230	198	0	G., F.	137	161	1 F., G.	3 F., G.	164	752	1 E., M.	2 E., G. and Ger.	246	57

E. = earthy; G. = grassy; M. = musty; F. = fishy; Ger. = geranium.

TABLE 4

Algae and flora present in raw water during indicated periods

SEASON	SOURCE	
Fall, 1930	Macopin Intake	None
	Echo Lake Brook	*Anabaena*, *Synura*, Uroglena, Cryptomonas, *Asterionella*
	Kanouse Brook	Synura
	Clinton Brook	None
	Oak Ridge Brook	*Asterionella*, *Dinobryon*, Anabaena, *Synura*
Winter, 1930–1931	Macopin Intake	Asterionella
	Echo Lake Brook	*Asterionella*, Melosira, Cryptomonas, Chroöcoccus
	Kanouse Brook	None
	Clinton Brook	None
	Oak Ridge Brook	*Dinobryon*
Spring, 1931	Macopin Intake	Synura, *Asterionella*, *Melosira*, Dinobryon
	Echo Lake Brook	*Asterionella*, Synura, *Melosira*
	Kanouse Brook	None
	Clinton Brook	*Synura*
	Oak Ridge Brook	*Dinobryon*, *Synura*
Summer, 1931	Macopin Intake	Dinobryon, Cryptomonas, Navicula, Fragilaria, Glenodinum, *Tabellaria*
	Echo Lake Brook	*Tabellaria*, Cryptomonas, Melosira, Navicula
	Kanouse Brook	Synura, *Tabellaria*, Synedra, Mallomonas
	Clinton Brook	None
	Oak Ridge Brook	Dinobryon, Synedra, Synura, *Fragillaria*

Note: Predominating seasonal species as *Asterionella*.

EXPERIMENTAL

The experiments to be discussed were performed in the late summer of 1931 and had as their object to determine whether or not

(*a*) Ammoniation in conjunction with chlorination would permit carrying higher and more persistent residuals without creating chlorinous tastes and odors.

(*b*) Preammoniation would assist in controlling the prolific algae growths encountered in the Cedar Grove Reservoir.

(*c*) Ammoniation would assist in preventing seasonal tastes and odors due to algae growths and enhanced by chlorination.

(*d*) The persistent residuals, reported by other workers as being a consequence of ammoniation, would assist in eliminating bacterial aftergrowths occurring in the distribution system and distribution reservoirs.

Numerous experiments were conducted in the Cedar Grove laboratory before actual field scale experiments were initiated. Samples of raw water were obtained from the intake, treated with ammonia and chlorinated. Samples were treated with chlorine alone at rates of 1.0, 1.2, and 1.5 p.p.m. and compared with samples to which had been added chlorine at rates of 0.8, 1.0, 1.2, and 1.5 p.p.m. and ammonia at rates of 0.25, 0.3, 0.4 and 0.5 p.p.m., respectively.

While in the samples treated with chlorine alone the bacterial count dropped off rapidly, only to rise to high figures within 48 hours of chlorine application, the ammonia-chlorine treated samples dropped to low counts somewhat more slowly, but the counts remained low.

To some of the samples, mud, taken from the 32 million gallon reservoir which acts as a sedimentation basin at the intake, was added, in an endeavor to learn whether or not tastes for which the presence of this mud was responsible, could be eliminated. Even aggravated tastes and odors caused by the addition of this mud in much greater than normal quantities, were satisfactorily eliminated with the ammonia-chloride treatment.

The successes encountered in laboratory work prompted the installation of a Wallace and Tiernan MDPA Ammoniator at the upper intake (on No. 1 pipe line), the Wallace and Tiernan Vacuum Chlorinator was reinstalled at a point some distance below the ammoniator (giving approximately 30 minutes contact following ammoniation and prior to chlorination) and field scale experimental work initiated. Water in No. 2 pipe line (from the lower intake) which has the added benefit of some sedimentation occurring in the 32 mg. reservoir, received only routine straight chlorination. By preventing any mixing of the water in the two pipe lines until they reached Great Notch, 17 miles below the intakes, it was possible to make comparisons of the two methods of treatment under the most ideal conditions.

These comparative tests have been carried on over a period of two

months, during which time pipe line No. 1 received varying ammonia-chlorine treatment, while pipe line No. 2 was treated with chlorine

TABLE 5

Experiment No. 1. Raw water treated with chlorine only

Series	Applied chlorine	After 1 hours' contact: Bacteria per cubic centimeter	After 1 hours' contact: B. coli group: Presumptive	After 1 hours' contact: B. coli group: Completed	After 24 hours' contact: Bacteria per cubic centimeter	After 24 hours' contact: B. coli group: Presumptive	After 24 hours' contact: B. coli group: Completed	After 48 hours' contact: Bacteria per cubic centimeter	After 48 hours' contact: B. coli group: Presumptive	After 48 hours' contact: B. coli group: Completed	After 4 days' contact: Bacteria per cubic centimeter	After 4 days' contact: B. coli group: Presumptive	After 4 days' contact: B. coli group: Completed
	p.p.m.												
a	1.0	3	0/5	0/5	10	0/5	0/5	11,540	0/5	0/5	48,000	0/5	0/5
b	1.2	12	1/5	0/5	7	0/5	0/5	6,400	0/5	0/5	56,300	0/5	0/5
c	1.5	19	0/5	0/5	9	0/5	0/5	1,290	0/5	0/5	62,500	0/5	0/5

Raw water: Bacteria per cubic centimeter = 1,670.

Presumptive tubes 5 out of 5. Completed tubes 1 out of 5.

Experiment No. 2. Raw water treated with chloramine (anhydrous ammonia and liquid chlorine)

Series	Applied: Cl_2	Applied: NH_3	After 1 hour's contact: Bacteria per cubic centimeter	After 1 hour's contact: B. coli group: Presumptive	After 1 hour's contact: B. coli group: Completed	After 24 hours' contact: Bacteria per cubic centimeter	After 24 hours' contact: B. coli group: Presumptive	After 24 hours' contact: B. coli group: Completed	After 48 hours' contact: Bacteria per cubic centimeter	After 48 hours' contact: B. coli group: Presumptive	After 48 hours' contact: B. coli group: Completed	After 4 days' contact: Bacteria per cubic centimeter	After 4 days' contact: B. coli group: Presumptive	After 4 days' contact: B. coli group: Completed
	p.p.m.	p.p.m.												
a	0.8	0.25	16	2/5	0/5	8	0/5	0/5	3	0/5	0/5	3	0/5	0/5
b	1.0	0.3	8	0/5	0/5	4	0/5	0/5	2	0/5	0/5	4	0/5	0/5
c	1.2	0.4	4	1/5	0/5	6	0/5	0/5	2	0/5	0/5	4	0/5	0/5
d	1.5	0.5	10	1/5	0/5	2	0/5	0/5	0	0/5	0/5	0	0/5	0/5

B. coli group determinations made by inoculating lactose broth tubes with 10 cc. of sample.

Raw water: Bacteria per cubic centimeter = 3,600.

Presumptive tubes 5 out of 5. Completed tubes 5 out of 5.

alone. Prior to the inauguration of this procedure, water in No. 2 pipe line as received at Great Notch, had always tasted somewhat better than did that in pipe line No. 1, this, of course, being attribut-

able to the sedimentation occurring in the 32 m.g. reservoir ahead of No. 2 pipe line intake.

During the whole period of these experiments separate records were kept of the bacteriological quality of the waters carried in the two pipe lines.

A composite picture of the results is presented in table 5.

Chlorination of No. 2 pipe line was carried on as before, i.e. with chlorine applied at the rate of 1.5 p.p.m. No 1 pipe was treated with ammonia at the rate of 0.25 p.p.m. and chlorine at the rate of 0.9 p.p.m. for a period of two weeks. During this period the observed ortho-tolidin residual at Great Notch inNo. 1 pipe line (NH_3-1 + Cl_2) was 0.6 to 0.8 p.p.m.—in No. 2 pipe line (Cl_2) 0.02 to 0.1 p.p.m. Subsequently ammonia treatment of No. 1 pipe line was increased

TABLE 6

PIPE LINE		RESIDUALS IN PARTS PER MILLION				
		Immediate	After 24 hours	After 48 hours	After 96 hours	After 108 hours
No. 1	Applied NH_3, 0.25 p.p.m., Cl_2–0.9 p.p.m.	0.9	0.3	0.25	0.12	0.01
No. 2	Applied Cl_2, 1.5 p.p.m.	0.12	0.02	0.03	0.02	0.015
No. 1	Applied NH_3, 0.3 p.p.m.; Cl_2, 1.0 p.p.m.	0.9	0.5	0.4	0.15	0.14
No. 2	Applied Cl_2, 1.5 p.p.m.	0.08	0.03	0.025	0.015	0.02

to 0.35 p.p.m. and chlorination maintained at the rate of 0.9 p.p.m. to determine if this would still further increase the residual without causing tastes and odors. No change in residual was obtained. One week later the treatment was again changed, the applied ammonia being cut to 0.3 p.p.m. and applied chlorine increased to 1.0 p.p.m. and this treatment continued for about one month. This gave a residual at Great Notch of 0.8 to 0.9 p.p.m.

Samples from both lines, collected at Great Notch, 17 miles (24 hours) after treatment were kept in 5 gallon carboys and ortho-tolidin tests made over a period of days with results as indicated in table 6.

At Great Notch the waters are thoroughly mixed and following this mixing residual chlorine tests of the combined waters show a reduction of some 50 percent to 0.4 p.p.m. At the outlet from Cedar Grove Reservoir residuals of 0.02 to 0.03 p.p.m. are found in the

combined waters. (While this reservoir has a storage capacity equivalent to 10 days water consumption it is believed that short circuiting across the basin actually reduces retention of incoming water to approximately five days.) In communities fed directly from the gravity mains, water being taken from point ahead of Cedar Grove Reservoir but subsequent to mixing at Great Notch, residuals of from 0.1 to 0.15 p.p.m. were found.

As a result of these sustained residuals samples from Cedar Grove Reservoir have been consistently free of gas formers. Hitherto the presence of occasional gas formers had necessitated additional chlorination at the reservoir. Bacterial counts in water coming to Cedar Grove Reservoir sometimes during periods of heavy rain running as high as 2000 per cubic centimeter, have never since the beginning of the ammonia-chlorine treatment exceeded 10 to 12 per cubic centimeter. Algae growths, formerly so prolific in Cedar Grove Reservoir as to require treatment with copper sulphate in amounts as high as 2000 pounds per season, did not make their appearance during the summer of 1931. Aftergrowths in the system have been practically eliminated. Samples from the distribution system currently examined by the State Board of Health and the Newark City Hospital Laboratory, in addition to our own examinations, have all reported frequent presence of positive gas formers prior to ammoniation. These have not been observed by any of the laboratories since practice of the ammonia-chlorine process was instituted.

Before introduction of ammonia, medicinal, at times grassy tastes, often described as typical chloro-tastes, were frequently noticed and these same tastes were present in the straight chlorinated water of pipe line No. 2 during the course of the experiments. These tastes were the subject of frequent consumer complaints and were often blamed on "too much chlorine" in the water at the consumers faucet.

It is amusing to contemplate the fact that now, with ammoniation, the water actually does carry a residual to the consumers tap throughout the area served, something it never did before, yet all complaints of tastes and odors have ceased. Even at the Cedar Grove Reservoir intake where relatively high residuals are found the taste of the water is considerably improved, only a very occasional straight chlorinous taste being encountered. This too, will be eliminated as it is intended to reduce these residuals somewhat after it is felt that the system is thoroughly sterilized.

CONCLUSIONS

As far as the Pequannock watershed supply is concerned

(*a*) Ammoniation in conjunction with chlorination does permit carrying higher residuals without creating chlorinous tastes and odors, and these residuals do persist for greatly extended periods, creating an added safeguard to the purity of this water supply.

(*b*) Preammoniation does control algae growths hitherto prolific in the Cedar Grove Reservoir.

(*c*) Ammoniation, in conjunction with chlorination, does prevent seasonal tastes and odors due to algae and microörganic growths.

(*d*) The persistent residuals to be secured through the use of ammonia-chlorine do tend to eliminate aftergrowths in the reservoirs and distribution system.

The writer wishes to make acknowledgment of his thanks to Mr. James W. Costello, Chief Engineer; Mr. Herman Rosentreter, Division Engineer, Mr. William C. Bank, Assistant Division Engineer Division of Water, Department of Public Affairs, Newark, and Mr. Robert Spurr Weston, Consulting Engineer, without whose generous approval and coöperation this work could not have been carried out.

UNACCOUNTED FOR WATER[1]

By P. J. Hurtgen[2]

Unaccounted for water is defined as "that portion of the water flowing into a distribution system which is not delivered to the consumers." It embraces such items as:

1. Leakage in distribution system and services.
2. Under-registration of meters.
3. Water used for municipal purposes, not metered.
4. Illegal connections.
5. Leaking flushing tanks in sewer systems.
6. Poorly maintained meters.

You all realize that it is impossible to maintain a distribution system without some loss and that there are some minor losses that do not justify the expense required to locate and repair them. Unaccounted for water is so general throughout the cities of the country that public service commissions take it into consideration when determining rate schedules.

BASIS OF DISCUSSION

For the purpose of this discussion I have prepared some data on unaccounted for water taken from pitometer surveys of seven Wisconsin cities, and I have allocated the unaccounted for water as set up in these reports to *Under-registration of Meters, Leaking Services* and *Leakage through Mains,* as in table 1. Practically all meters that came within this survey were large meters. These surveys do not ordinarily give you much definite information on individual small meters. Testing of the small meters can be, and usually is carried on exclusively by the water department.

I have also procured some data from the reports to the Public Service Commission, covering 14 of the largest cities of Wisconsin, which are set up in table 2.

In making an analysis of these data it is to be noted that the 7

[1] Presented before the Wisconsin Section meeting, October 27, 1931.

[2] Director of Public Works, Kenosha, Wis.

cities which are from 91 to 100 percent metered account for from 77 to 79 percent of the total water pumped, while one city that is 99

TABLE 1

Data on unaccounted for water, based on pitometer surveys of seven Wisconsin cities

CITY	TOTAL PUMPAGE	ACCOUNTED FOR WATER	PERCENT ACCOUNTED FOR	UNACCOUNTED FOR WATER	LEAKING CHARGED TO		
					Meters	Services	Mains
	m.g.d.	*g.d.*			*g.d.*	*g.d.*	*g.d.*
1	1,830,000	1,427,000	78	403,000	49,000	284,000	70,000
2	1,731,000	1,262,400	73	468,600	38,600	430,000	None
3	3,502,000	3,022,000	86	480,000	451,000	7,000	22,000
4	3,728,000	3,544,400	95	183,600	66,100	117,500	
5	3,650,000	3,213,000	88	437,000	297,000	84,000	56,000
6	5,715,000	5,544,000	97	171,000	20,000	102,000	49,000
7	584,000	497,500	85	86,500	9,000	54,000	23,500
	20,740,000	18,510,300	89	2,229,700	930,700	1,078,500	220,500
Average percent.			89	100	4.5	5.2	1.3

TABLE 2

CITY	PERCENT METERED	PERCENT WATER SOLD THROUGH METERS	GALLONS WATER PUMPED PER		
			Capita per day	Service per day	Meter per day
1	100	77	145	Not available	711
2	100	77	102	504	383
3	100	77	104	525	404
4	99	55	63	253	140
5	97	60	72	313	191
6*	94	77	72	300	245
7	92	78	121	486	412
8	91	78	106	451	397
9	91	79	103	390	343
10	89	56	80	287	182
11	87	58	114	534	359
12	84	74	106	406	365
13*	50	33	102	319	276
14	37	43	155	429	499

* Privately owned plants.

percent metered accounts for only 55 percent through meter registration, which indicates a very large loss through leakage somewhere

in the system. The cities that are from 84 to 89 percent metered account for an average of 64 percent of the water pumped through meter registration. This also appears to be too low. City no. 14 which is 37 percent metered runs an average of 499 gallons of water per metered service. While this is very high, it is probable that this city has meters on the large services, which would account for the high rate per service. This same city, however, also has the highest per capita consumption per day. The penalty for not metering is reflected in this particular case.

DATA FOR KENOSHA

I have prepared some data pertaining to the water works system of the City of Kenosha, with the thought that the information might be of value to other cities and particularly to cities that, like Kenosha, are 100 percent metered.

In 1923 the Pitometer Company made a survey of our entire distribution system, and they reported as follows: "No material leakage was found to exist in the mains, with the exception of that found in the South Harbor crossing, amounting to 22,000 gallons per day and 7,000 gallons per day on various other sections of mains, including services." "Three minor service leaks were found, these being in all cases inside the curb stops." "This showed that the mains and services were in excellent condition."

Loss per twenty-four hours through under-registration of meters was found to be 451,000 gallons per day, all of which was found on meters (two 4-inch and four 6-inch). They further stated that meters on domestic supply lines were found to register correctly in most cases, those found to be slow being either old meters, or those in which a few of the meters were obstructed by dirt. Based on this report, we were accounting for 86 percent of our total pumpage, which included water used for municipal purposes, and the loss, therefore, from their report was allocated as follows:

94 percent to the large meters
5 percent to harbor crossing
1 percent to services

Prior to this survey the meter department was making monthly inspections and readings of the large meters and without question would have discovered the fact that these large meters failed to register properly. Since 1923, all large meters are read and inspected bi-monthly. After these six meters were conditioned, the only other

material leak was in the Harbor Crossing, amounting to 22,000 gallons daily. To repair this leak would require marine equipment, which would entail an expenditure which we did not believe was warranted considering the fact that only 8,030,000 gallons of water was lost per year. Notwithstanding this favorable report we believe that the small cost of the survey was warranted, in that it provided us with reliable data regarding our entire waterworks system.

Condition of present system

Because of the fact that this survey was made eight years ago, it is more or less problematical as to how to allocate our unaccounted for water at the present time. However, by comparing our output from our pumping station records with the sum of the meter registrations, we find, that our meters record 77 percent of the water pumped into the distribution system. We have been more or less lenient with contractors by permitting the use of fire hydrants on paving work, flooding sewer trenches, also city sewer department for sewer flushing and other municipal activities. The use of the hydrants, however, for these purposes is under the jurisdiction of a city inspector, or city employees. Street sweeper operators must report daily the gallons of water used based on the capacity of the sweeper tank. Water used by the city department for flushing sewers and water used by the water department for flooding trenches and flushing mains is accounted for by recording the time the hydrant is in use together with the number of openings. The fire department likewise furnishes these data, and from this information we estimate the quantity of water used. Water used by paving contractors is based on 10 gallons of water per square yard of concrete, which includes sprinkling the sub-base. This plan is also followed in determining the amount of water used by the street maintenance department, and from these combined data we believe we estimate with reasonable accuracy the amount of water supplied for municipal purposes. Our average over a period of three years for municipal work has been 9 percent of the total yearly pumpage.

The Pitometer Company considers 3,000 gallons per day per mile of pipe a reasonable allowance for unavoidable underground leakage in the distribution system, which in Kenosha on this basis would amount to 7 percent of our yearly pumpage. You will note that I have considered a minimum percentage due to leakage in mains I am justifying this in part because of the results of the survey of the

system, together with the fact that the water department constructs all water mains and our water department construction crew consists of practically the same organization that we have had for the past eighteen years. The loss through meter slippage is problematical. Water waste survey engineers consider that from 3 to 5 percent is a reasonable allowance. I am assuming therefore that we may have a loss of 4 percent through meter under-registration, and there, therefore, would remain 3 percent to charge against service leaks. This set up, therefore, would be, as follows:

77 percent accounted for through meter registration
9 percent estimated municipal use
7 percent estimated main and joint leakage
4 percent estimated meter under-registration
3 percent estimated service leakage
100 percent

Main and joint leakage

The best method of determining leaks in the distribution system is by means of a Pitometer survey. However, the electric leak detector and locater is also most valuable in detecting and locating leaks in both mains and services. The aquaphone is a valuable piece of equipment for locating service and fixture leaks. Many leaks have been found by examining the manholes on both the sewer system and utility company's duct manholes, for quite frequently water will enter the ducts and flow to a manhole. Cities can well afford to equip themselves with some of these facilities for leak detection, and can also make inspections of sewer systems and utility ducts as these are not only effective, but also inexpensive means of discovering leaks in the distribution system. An occasional check up might well be made for unaccounted for water to keep it within economical limits, the money value of which will depend on local conditions. Unless it is kept within certain limits a substantial loss of revenue will result.

Purification, pumping and treating of water represent invested capital in plant, and in supplies operation and maintenance, and it should, therefore, be conserved as is any other commodity. By so doing it will defer the time when it will be necessary to add additional pumping and power units, together with additional buildings to house this equipment.

Meter under-registration

Prior to 1928 we had no definite meter testing schedules. Meters were removed for testing only when they ceased to register or when there was reason to believe that the meter was not functioning properly. However, since the beginning of 1928 we have laid out a program which contemplates the testing of meters every six years. With this in mind we commenced the test in the oldest section of the city, because, by so doing, we covered the area where the meters were longest in service. Meters from $\frac{5}{8}$ to 2 inch inclusive are tested in the field with a portable test meter.

Meters that test unsatisfactory are brought in to the meter repair shop for attention. We have during the past two years tested 3,102 meters of various sizes. Of a total of 2,938 field tested $\frac{5}{8}$ inch meters, 72 percent were satisfactory. Of a total of 112 field tested $\frac{3}{4}$ inch meters, 82 percent were satisfactory. Of a total of 30 field tested 1 inch meters, 90 percent were satisfactory. Of a total of 16 field tested $1\frac{1}{2}$ inch meters, 90 percent were satisfactory. Of a total of 6 field tested 2 inch meters of disc and torrent type 67 percent were satisfactory.

This field test indicates that 28 percent or 826 of the 2,938, $\frac{5}{8}$ inch meters did not meet the required test. Of this number, however, 170, or 21 percent registered 100 percent on a flow of 28,800 gallons per day.

211, or 26 percent registered 3.8 percent over on a flow of 28,800 gallons per day.

351, or 42 percent registered 4.8 percent under on a flow of 28,800 gallons per day.

74, or 11 percent did not register on a flow of 28,800 gallons per day, which is $2\frac{1}{2}$ percent of total meters tested.

14, or 18 percent registered satisfactorily on a flow of 16,000 gallons per day.

209, or 24 percent registered 3.5 percent over on a flow of 16,000 gallons per day.

380, or 46 percent registered 4.9 percent under on a flow of 16,000 gallons per day.

96, or 12 percent did not register on a flow of 16,000 gallons per day.

826, 100 percent which is $3\frac{1}{3}\%$ of total meters tested.

432, or 52 percent registered 13 percent under on a flow of 1,080 gallons per day.

394, or 48 percent did not register on a flow of 1,080 gallons per day.

826, or 100 percent equals 14% of total meters tested.

The field test indicated that of the 112 ¾ inch meters, 82 percent or 92 meters tested satisfactory on flows down to 1,080 gallons per day. The test on the 20 meters that did not meet the requirements is as follows:

1 meter showed 100 percent registration at 28,800 gallons per day.

8 meters showed 2.5 percent over registration at 28,800 gallons per day.

9 meters showed 6.3 percent under-registration at 28,800 gallons per day.

2 meters showed no registration at 28,800 gallons per day.

20 total.

1 meter indicated 100 percent registration at 16,000 gallons per day.

3 meters indicated 4 percent over registration at 16,000 gallons per day.

14 meters indicated 5.2 percent under-registration at 16,000 gallons per day.

2 meters indicated no registration at 16,000 gallons per day.

20 total.

1 meter indicated 3 percent over registration at 1,080 gallons per day.

7 meters indicated 15.5 percent under registration at 1,080 gallons per day.

12 meters indicated no registration at 1,080 gallons per day.

20 total.

Sixteen 1½ inch meters were included in the field test at which 14 or 90 percent registered satisfactorily with flows to 1,080 gallons per day. The tests on the other two meters were as follows:

1 meter registered 5 percent over on a flow of 28,800 gallons per day.

1 meter registered 1 percent under on a flow of 28,800 gallons per day.

2

1 meter registered 5 percent over on a flow of 16,000 gallons per day.

1 meter registered 30 percent under on a flow of 16,000 gallons per day.

2

Neither meter registered at a flow of 1,080 gallons per day. Six 2-inch meters were tested in the field. Of these 4 were satisfactory.

2 meters registered 10 percent under on a flow of 28,800 gallons per day.

2 meters registered 4.5 percent under on a flow of 16,000 gallons per day.

2 meters did not register on a flow of 1,080 gallons per day.

Twenty $\frac{5}{8}$-inch meters of various makes were taken off the lines and tested in the shop for flows of 100 gallons per day with the following results:

Number of meters	*Percent under-registration*
5	Failed to register
1	34
1	26
1	14
2	10
2	8
2	7
1	6
2	4
1	3
2	2

As previously stated we conducted these meter tests in a district where the meters had been longest in service, which covered about 90 percent of one of the billing districts. Prior to these tests our revenue from this district, exclusive of industrial use, was $20,154.46, which covered the 6-month winter period. The following winter period, after testing and conditioning 90 percent of the meters in this district, our revenue increased to $21,793.10, and the revenue during the next winter period was $22,017.31. Very few residences were added in the meantime, and we have credited the major increase in revenue to the conditioning or the meters. We have two portable test meters, and we send the men out on this work during spare time and the meters that do not test satisfactorily are delivered to the meter shop for repairs.

Eight new meters tested at the factory were taken from stock and tested with the following results:

All meters tested within proper limits on all flows down to 360 gallons per day. At the rate of 100 gallons per day.

Number of meters	*Percent under-registration*
4	did not register
1	50
1	25
1	35
1	150

(compare with above)

Ten percent of old meters registered satisfactorily on flow of 100 gallons per day. Of 8 new meters none registered satisfactorily on flow of 100 gallons per day.

It is quite apparent from these records that household meters are not designed to register the small fixture leaks, which in the aggregate result in considerable unaccounted for water, and this small flow loss increases with the age of the meter. It would appear, therefore, that meter manufacturers might well give this matter some thought and lend their efforts toward the development of meters that will register with greater accuracy on the minimum flows. It appears also that water utilities could profit by periodic tests of the household meters, say every five to six years and once a year on larger meters.

It is also apparent from the under-registration of the $\frac{3}{4}$- to 2-inch meters on the low flows that the utility should not only determine the size of the meters, but should also exercise care in limiting the sizes to the actual requirements in each case. In Kehosna the distribution of sizes of meters is as follows:

Percent of meters	*Size, inches*
95	$\frac{5}{8}$
2	$\frac{3}{4}$
2	1 to 2 inclusive
1	2 to 10 inclusive

The one percent includes fire line meters.

Mr. Howson of the firm of Alvord, Burdick and Howson, Engineers, made a study and analysis of the statistics from 44 cities in various sections of the country on the subject of "unaccounted for water,"

which was presented[3] at the 1928 meeting of the Association and because of the fact that his studies covered an enormous mileage of distribution mains together with a vast number of meters of all sizes, I feel that this paper would have little value if I did not present his conclusions on this important subject. These conclusions were as follows:

1. "Cast iron, or steel pipe with other than screwed joints is best from the leakage standpoint."

2. "Lead and copper services are better materials, from the leakage standpoint, for the laying of service pipes than is wrought iron."

3. "It is to the utility's interest to own the meters. The advantage, expressed in unaccounted for water of the utility, rather than the consumer owning the meter is approximately 3.8 percent of all water pumped, or 6 percent of the water sold."

4. "The utility rather than the consumer should decide as to the size of meter to install."

"This decision is worth to the utility approximately 4.4 percent of the water pumped or 6.25 percent of the water sold."

5. "There is some advantage from the standpoint of unaccounted for water in charging for, as well as metering, all public water uses."

And he made the following suggestions:

1. "All services should be of lead (or copper) and these materials should extend from the mains to the meters rather than to the property line only, in the case of inside meter settings.

2. "There is need of an accurate means for testing water meters at small flows without removal from service. The standard tests of water meters which do not go below about 360 gallons per day (three times the average use of the ordinary consumer, if used at a uniform rate throughout the day) is too high. Meters should not only be able to register small flows more accurately, but there is need for a portable device which will permit of checking the ability of meters to measure small flows with small expenditures for testing.

3. "The utility should own all meters and maintain them according to its own standards.

4. "The size of meters installed should be as small as practicable for the service. Larger pipe and smaller meters should be the aim."

In conclusion, I believe the periodic testing of meters will, to a great extent, obviate the necessity of billing the patrons based on average consumption, which invariably causes an argument between the collector and patron and arouses a suspicion that the water utility is taking, for itself, all benefits of any doubt that may exist in reference to the water bill.

[3] Journal, September, 1920, page 349.

PER CAPITA WATER CONSUMPTION[1]

By Ezra B. Whitman[2]

The consumption of water, its variation and how it may be reasonably estimated, are matters which will be discussed in this paper.

During the past five or six years our office has had occasion to study the per capita water consumption of a number of cities where the conditions varied widely. These studies were made in connection with the diversion of water from Lake Michigan by Chicago, the proposed diversion of water from the Connecticut River for the water supply of Boston, the proposed diversion of water from the Delaware River by the City of New York, the new water supply for the City of Albany, the increased water supply of the City of Lynchburg, Virginia, the increased water supply for the City of Frederick, Maryland, a study of water supply conditions in Fall River, Massachusetts, and a study of the water consumption in Baltimore City proper and the adjacent county areas.

A study of the water consumption in each one of these places brings out very forcibly the fact that the water consumption of each individual place is a problem all to itself. While studies of consumption in other cities may act more or less as a guide, if information is lacking in the particular city under consideration, yet such comparative figures should be used with a great deal of discrimination. It will be interesting to note the difference in the per capita consumption in these different cities from the information which we have gathered.

The water consumption in Chicago from 1920 to 1928 is shown in table 1 prepared by the Sanitary District of Chicago.

The population and use of water in the Metropolitan District around Boston from the year 1895 to 1926 are shown in table 2.

Information obtained with regard to New York's water consumption from the Department of Water Supply, Gas and Electricity, is shown in table 3.

[1] Presented before the Four States Section meeting, April 1, 1931.

[2] Of Whitman, Requardt and Smith, Engineers, Baltimore, Md.

From the years 1906 to 1916, efforts were made to cut down the water consumption in New York, while the new Catskill supply was being developed, as there was danger of a water shortage. House to

TABLE 1

Water consumption in Chicago

YEAR	PUMPAGE UNCORRECTED FOR WASTE			AVERAGE G.P.C.	POPULATION IN CHICAGO—THOUSANDS, S.D.C. ESTIMATED
	Annual average	Maximum month	Maximum day		
	m.g.d.	*m.g.d.*	*m.g.d.*		
1920	775	805	835	276	2,729
1921	785	872	922	276	2,784
1922	800	823	923	275	2,839
1923	805	855	953	271	2,894
1924	845	878	916	278	2,949
1925	888	940	985	286	3,004
1926	885		1,022	286	3,048
1927	943		1,036	293	3,103
1928	1,041		1,151	320	3,157

TABLE 2

Water consumption in Boston Metropolitan District

YEAR	ANNUAL AVERAGE CONSUMPTION	POPULATION SERVED	AVERAGE PER CAPITA CONSUMPTION	PERCENT METERED
	m.g.d.		*g.p.d.*	
1895	67.5	735,000	92	
1900	96	840,000	114	
1905	118	915,000	129	11
1910	113	1,030,000	110	37.5
1915	102	1,160,000	88	66
1920	127	1,205,000	105	75
1921	117	1,225,000	95	77
1922	119	1,245,000	95	80
1923	125	1,265,000	99	82.5
1924	124	1,285,000	97	95
1925	128	1,305,000	98	96
1926	130	1,330,000	98	97

house inspection for leakage was carried out from time to time throughout this period, and an examination of table 3 will show the consumption of water was held almost stationary during this period, in spite of a growth in population of a million people. With the

introduction of the new supply from the Catskills and the stopping of the propaganda for conservation of water, it will be seen how rapidly the consumption has climbed from 1916 to 1924, while, since 1924, the per capita consumption for four years was practically stationary.

TABLE 3

Water consumption in New York City

YEAR	POPULATION	ANNUAL CONSUMPTION	PER CAPITA CONSUMPTION
		m.g.d.	*g.p.d.*
1907	4,314,237	513.0	118.9
1908	4,469,248	518.6	116.0
1909	4,632,088	512.7	110.7
1910	4,785,190	529.6	110.7
1911	4,873,069	494.4	101.5
1912	4,960,948	505.0	101.8
1913	5,048,827	499.1	98.9
1914	5,136,706	544.4	106.0
1915	5,224,585	528.2	101.1
1916	5,312,464	566.2	106.6
(Catskill supply introduced in 1916)			
1917	5,400,343	584.6	108.3
1918	5,488,222	659.2	120.1
1919	5,576,191	660.2	118.4
1920	5,643,440	734.9	130.2
1921	5,690,223	731.3	128.5
1922	5,737,006	742.5	129.4
1923	5,783,789	761.6	131.7
1924	5,830,573	780.2	133.8
1925	5,877,354	839.6	142.9
1926	5,986,356	863.3	144.2
1927	6,107,268	868.1	142.1
1928	6,208,178	879.3	141.6

The water consumption in the City of Baltimore is shown in table 4.

The figures in table 5, taken from the annual report of the City of Lynchburg for the year ending December 31, 1929, are quite interesting, as this city adopted a program of complete metering at the beginning of 1921, which was completed about the middle of 1929.

The figures on the water consumption at Fall River, Mass., taken from the January 1, 1930, Report of the Watuppa Water Board to

the City Council of the City of Fall River, Massachusetts, are shown in table 6.

TABLE 4
Water consumption in Baltimore

YEAR	AVERAGE DAILY CONSUMPTION	POPULATION	PERCENT OF TAPS METERED	PER CAPITA CONSUMPTION	MAXIMUM AVERAGE DAILY CONSUMPTION FOR 1 MONTH
	m.g.d.			*g.p.d.*	*m.g.d.*
1885	26.9	367,000	1.3	73	31.9
1890	41.0	435,000	1.6	94	47.8
1895	57.1	471,000	1.6	121	65.2
1900	56.6	510,000	1.7	111	75.5
1905	64.8	538,000	2.7	120	71.2
1909	69.4	558,000	3.3	123	78.0
1910	60.0	560,000		128	
1915	72.0	585,000		124	
1918	108.0	600,000	4.0	180	
1920	95.0	734,000		129	
1925	98.0	797,500	12.5	123	
1926	102.0	810,000		126	
1927	112.0	822,500		136	
1928	110.0	835,000		132	
1929	110.0	849,000	24.5	130	130.0
1930	113.0	860,000	25.8	132	132.0

TABLE 5
Water consumption in city of Lynchburg, Va.

YEAR	AVERAGE DAILY CONSUMPTION	AVERAGE DAILY PER CAPITA CONSUMPTION	PERCENT OF SERVICES METERED
	m.g.d.	*g.p.d.*	
1921	5.9	158	16
1922	5	135	25
1923	4.6	128	38
1924	4.75	135	47
1925	4.9	136	59
1926	4.5	127	67
1927	4.65	121	78
1928	4.4	113	87
1929	3.9	100	97
1930	3.85	97	100

It will readily be seen from a study of the foregoing figures that the water consumption in each city is a problem unto itself. Before

determining upon the source of a new or additional supply for a community, it is, of course, necessary to know the probable consumption or demand for water in that community.

DIVISIONS IN THE USE OF WATER

In estimating the probable future growth of water consumption in a City, an analysis should be made of the various uses to which the water will be put. These uses may be generally classified as industrial and commercial, domestic, public uses and unaccounted for water, including leakage from mains and house services, slippage of meters, plumbing leakage and waste.

TABLE 6

Consumption in Fall River, Mass.

YEAR	AVERAGE DAILY CONSUMPTION FOR YEAR	AVERAGE DAILY CONSUMPTION—MAXIMUM MONTH	PER CAPITA CONSUMPTION
	m.g.d.	*m.g.d.*	*g.p.d.*
1875	0.813	0.946	70.38
1880	1.36	1.69	37.15
1885	1.46	1.83	30.87
1890	2.15	2.85	30.96
1895	3.14	3.81	36.79
1900	3.80	4.48	36.40
1905	4.41	5.08	41.95
1910	5.21	5.59	43.83
1915	6.10	6.50	49.06
1920	6.39	6.93	51.37
1925	7.06	7.58	54.61
1929	6.26	6.71	52.74

In connection with the industrial use of water, not only should the present industrial use be studied, but as far as is possible, a forecast should be made of future industries and their character.

As an example of the great effect which industry may have on the water consumption of a town, we might cite the City of Cumberland, Maryland, where one manufacturing plant came into the town and requested the city to give it five million gallons of water per day, thus almost doubling the daily consumption.

With regard to the domestic use of water there has been a tendency toward increased use for such purposes over a considerable period of years. Not only has there been an increase in the bathing habit,

but in such a city as Baltimore, the recent growth of the city has been largely in areas where single houses with lawns around them have developed, whereas, formerly, Baltimore was almost entirely a city of block houses with practically no lawns. This development has meant a tremendous peak load in the hot dry months of the summer during the latter part of the afternoons when lawn sprinkling is usually carried out.

In Frederick, Maryland, during the past summer, when the sprinkling of lawns and flower beds was stopped because of the diminishing

TABLE 7

Water consumption data—Chicago, Ill.

CLASSIFICATION	GALLONS PER DAY											
	1920		1921		1922		1923		1924		1925	
	Per capita	Percent	Per capita	Percent	Per capita	Percent	Per capita	Percent	Per capita	Percent	Per capita	Percent
Industrial and commercial	56	20	52	19	52	19	53	19	54	19	55	20
Domestic metered	16	6	18	7	19	7	20	7	21	7	20	7
Domestic unmetered—legitimate usage	48	18	47	18	47	18	47	16	47	16	40	14
Free water, public, religious, educational and charitable	10	4	10	4	10	4	10	4	10	3	10	3
Free water, parks and boulevard	6	2	6	2	6	2	6	2	6	2	6	2
Underground street—leakage, slippage of meters, waste	13	5	13	5	13	5	13	5	13	5	28	10
Plumbing leakage and willful waste	120	45	122	45	120	45	135	47	139	48	121	43
Total	269	100	268	100	267	100	284	100	290	100	280	100

water supply, several owners of houses complained that they would much rather pay a higher rate for water and have all they wanted to use, than run the risk of destroying hundreds of dollars worth of lawns and shrubbery for lack of water.

An estimate of the distribution of water in gallons per capita per day for the City of Chicago is given in table 7, the data for which were taken from the *Journal of the Western Society of Engineers*, Volume 29.

It will be seen from table 7 that nearly one-half of the water in Chicago is estimated to be plumbing leakage and wilful waste.

The percentages of water used in various places for different purposes are shown in summary in table 8.

Analyzing the figures in regard to the distribution of water in Chicago, it is seen that the domestic use of water on the metered services increased from 16 in 1920 to 20 gallons in 1925. From still earlier figures available, the domestic metered consumptions in Chicago from the year 1913 to 1919 inclusive, were as follows: 9, 11, 11, 12, 13, 14 and 15 g.p.c. This, we believe, is the ordinary experience in the domestic use of water and is due to the higher standards of living as far as cleanliness is concerned, as well as the increasing tendency to have lawns and flower beds in most cities, and particularly in the suburban sections.

TABLE 8

Distribution of water uses, in percent

	FALL RIVER	LYNCHBURG	BALTIMORE	ESTIMATE OF AVERAGE USE IN AMERICAN CITIES*
Domestic	63	36	38	35
Industrial		25	31	30
Public	16	11	8	10
Unaccounted for	21	28	23	25
	100	100	100	100

* Turneaure and Russell, "Public Water Supplies."

In 1930, the domestic, including the institutional, use in Baltimore was 48.4 percent, and in Lynchburg, the use of water for these two items was 36 percent, while in the estimated average use in American cities in Turneaure and Russell "Public Water Supplies" it was 35 percent. It is noted that the commercial and industrial use of water in Lynchburg at present stands at about 25 percent, while in Baltimore it is 30.8 percent, and nine typical industrial American cities show a variation in industrial and commercial use of water from 15 to 65 percent, average 32 percent. In Fall River, the domestic and industrial use of water was about 63 as compared with 61 percent in Lynchburg, 69 in Baltimore and 65 for the average American city.

The municipal use of water in Lynchburg was 11 percent or 10 gallons per capita daily. In Baltimore it was 7.7 percent or 9 gallons per capita. A number of years ago, the cities of Indianapolis, Indiana; Rochester, New York; Newton, Massachusetts, ranged

from 3 to 5 gallons per capita for municipal use, while in Fall River, the percentage of water used for public purposes is 16 percent, or approximately 9 gallons per capita.

Water unaccounted for in various American cities has ranged as high as 50 percent and over. This item includes water lost in leaks, broken services and mains, leaks from faulty joints, slippage in the service meter and stolen water, errors made in calculations of public use of water at fires, flushing streets, etc. The Lynchburg figures for water unaccounted for is 28 percent or 26 gallons per capita. Leakage in Baltimore was 23 percent or approximately 29 gallons per capita. Twelve representative American cities showed water unaccounted for to average 25 percent, with a minimum of 14 and a maximum of 44 percent.

DECREASE IN USE OF WATER DUE TO METERS

The universal experience throughout the country where meters have been installed, has been a sharp reduction in the use of water. Because the water consumption then begins to rise after the complete installation of meters, it has been argued that meters lose their usefulness in stopping waste. As an example, the City of Cleveland, about 1895, was using over 160 gallons per capita per day, and with the complete installation of meters over a period of ten years, this per capita consumption dropped to less than 100 gallons per day per capita. Since the installation of meters, there has been a gradual increase in the use of water, until the consumption in 1928, was about 140 gallons per capita. This increased consumption, even with complete metering, is the general experience, although not universally so, and will be discussed more fully under a different heading.

Lynchburg, during the period from 1920 to 1930 when most of the completely metered supplies in other cities were increasing in per capita use, with the installation of meters, decreased from 158 in 1921 to 97 gallons in 1930.

Detroit, in 1910–13, with less than 25 percent of meters installed, had a water consumption of over 160 gallons per capita, and this had fallen, in 1925, with between 75 to 100 percent of the services metered, to 130 gallons per capita.

Columbus, in 1900, with less than 25 per cent of the services metered, had a water consumption of approximately 150 gallons, while in 1905, with between 75 and 100 percent of the services metered, the consumption had fallen to 60 gallons per capita. Many

other examples might be cited showing the decreased use of water after metering.

In Chicago, recognizing this decrease due to meters, Colonel Henry A. Allen estimated that, with complete metering, the per capita consumption throughout the City would drop from around 300 gallons to approximately 145 gallons per capita, while the engineers of the Sanitary District of Chicago estimated that the annual consumption, after complete metering, would be 160 gallons per capita. In Baltimore, Messrs. Nicholas S. Hill, Jr., and James H. Fuertes, estimated in 1920 that, if the City were completely metered by 1930, the per capita consumption would drop from 193 gallons per capita to 144 gallons per capita. In our own estimates of the effect of meters in the City of Frederick, Maryland, we estimated that the city would save at least 30 percent of its present water consumption.

Last summer, before restrictions were placed on the use of the water during the hot dry weather of the early summer, the per capita water consumption had risen to 180 gallons per capita in Frederick. This city has no large industrial users of water and it is undoubtedly true that much of the water used is wasted. In fact, during the past winter, after a house to house inspection of water fixtures and the discovery of some underground leaks by means of the aquaphone, the water consumption in Frederick was cut 20 gallons per capita.

In New York City, Mr. Arthur S. Tuttle of the New York City Board of Estimate and Apportionment, estimated that the full use of meters if installed in New York beginning in 1927, would by 1932, reduce the per capita use from 145 to 122 gallons per day, or 16 percent. This would mean that there would be 165 million gallons per day of water saved in New York City, and such a saving would be equivalent to a corresponding increase in the water supply. On December 31, 1926, there were 553,857 taps in New York City and about 25 percent of them were already metered, leaving about 415,000 unmetered services in New York City at that time. Figuring that there would be an increase of 85,000 unmetered services by 1932, this would give about 500,000 services without meters.

The cost of installing meters depends upon whether the meter is put on the inside of the building or installed in the sidewalk on the outside of the building. From figures secured from a number of cities, the cost of installing meters on the inside of the building ranges from 11 to 15 dollars, while the outside costs run from 25 to 30 dollars.

INCREASE IN USE OF WATER AFTER METERING

In Boston, Massachusetts, in 1907, with 18 percent of the services metered, the per capita water consumption was 109 gallons. By 1915 the percentage of meters installed on the services had increased to 66 percent, and the per capita consumption was reduced to 88 gallons. In spite of the fact that the number of meters increased from 66 to 96 percent in 1925, the per capita consumption had increased to 98 gallons. In other words, the increase per capita consumption was 10 gallons per capita in spite of the percentage of services metered being increased from 66 to 96 percent.

In Cleveland, Ohio, the water consumption in 1910, with 100 percent installation of meters, was 96 gallons per capita. In 1920, the per capita consumption had increased to 144 gallons per capita, an increase during this decade of 48 gallons. From 1920 to 1928, however, there was a falling off in the per capita consumption to 141 gallons. The increase from 1910 to 1928 was 45 gallons, or at the average rate of $2\frac{1}{2}$ gallons per year.

In Columbus, Ohio, in 1915, the average per capita consumption, with 95 percent of the services metered, was 80 gallons, while in 1925, with 99 percent of the services metered, the consumption was 93 gallons, or an increase of 13 gallons per capita in 10 years.

In Hartford, Connecticut, in 1907, with 98 percent of the services metered, the per capita consumption was 70 gallons, while in 1927, with 96 percent of the services metered, the consumption had increased to 84 gallons, or an average of 7 gallons per decade.

In Providence, Rhode Island, in 1917, with 94 percent of the services metered, the per capita consumption was 66 gallons, while in 1927, it had increased to 71 gallons, or an average of 5 gallons per decade. During the intervening years, however, the consumption had been as high as 80 gallons per capita, and from 1920 to 1925 averaged over 80 gallons per capita.

In Rochester, New York, in 1908, with 87 percent of the services metered, the per capita use was 80 gallons, and this in 1927 had increased to 100 gallons per capita, an increase of 10 gallons per decade.

In Milwaukee, Wisconsin, in 1908, with 98 percent of the services metered, the per capita consumption was 91 gallons, while in 1927, with 99 percent of the services metered, the per capita consumption had increased to 128 or 19 gallons per decade.

In our estimates of the future water consumption of the City of

Lynchburg, with the city 100 percent metered in 1930, we figured that the increase per decade per capita consumption would be at the rate of 11 gallons.

The figures above stated are shown in table 9.

There are a few cities where there has been a decrease in water consumption after metering. One example of this is the City of Detroit, Michigan. With 98 percent of the services metered in 1921, the per capita water consumption was 143 gallons, while in 1927, with 99 percent of the services metered, the consumption had dropped to 126 gallons. It is difficult to state what has been the cause of this decrease, but we do know that there has been, in recent years, much more work done in locating underground leaks by the use of the pitometer than was done several decades ago. It is probable that in a

TABLE 9

CITY	YEAR	PER-CENT ME-TERED	G.P.C.	YEAR	PER-CENT ME-TERED	G.P.C.	IN-CREASE PER DECADE
							g.p.c.
Boston, Mass.	1915	66	88	1925	96	98	10
Cleveland, Ohio	1909	99	87	1927	100	128	20
Hartford, Conn	1907	98	70	1926	96	84	7
Providence, R. I.	1917	94	66	1927	98	71	5
Rochester, N. Y	1908	87	80	1927	99	100	10
Milwaukee, Wis.	1908	98	91	1927	99	128	19
Columbus, Ohio	1915	95	80	1925	99	93	13

number of the cities where meters have been installed, the decrease has not been due entirely to metering, but has also been due to other causes, such as the location and stoppage of underground leaks, and also to the development of private supplies for large industrial users.

PAST PREDICTIONS OF THE USE OF WATER COMPARED WITH ACTUAL WATER CONSUMPTION

It is interesting and instructive to examine some past predictions of water consumptions and see how closely they have been approached by the actual use of water in certain cities. In 1909, Messrs. Freeman and Stearns submitted a report to the City of Baltimore in which they estimated that the population in Baltimore would be 850,000 in 1930 and that the probable quantity of water used per capita per

day would be 145 gallons, with a total quantity of water used per day of 123 million gallons. The actual population being served with water by the City of Baltimore was, in 1930, approximately 860,000, with a per capita consumption of 131 gallons per day and the total amount of water required by Baltimore per day, was 113 million gallons during that year.

This is an accurate estimate for a period of twenty-one years, and considering the fact that the number of metered services in Baltimore has increased from about 4 to 25 percent, and that Baltimore has carried on quite extensive pitometer surveys for underground leaks, as well as carrying out a house to house canvass for plumbing leaks on the unmetered services, this estimate is remarkably accurate. None of these things were foreseen by Messrs. Freeman and Stearns at the time they made their estimate.

In 1920 the per capita consumption in Baltimore was 166 gallons per capita and Messrs. Hill and Fuertes estimated that on the unmetered basis, the water consumption in Baltimore would be 193 gallons per capita in 1930, with a total consumption of 175 million gallons a day. The actual results as already stated are that the water consumption in 1930 was at the rate of 131 gallons per capita and the total consumption was 113 million gallons per day. Messrs. Hill and Fuertes estimated that the population in Baltimore in 1930 would be 905,000, while the population being served with water by the Baltimore City Water Department was 860,000. The actual total consumption in Baltimore in 1930 was almost identically the same as it was in 1920, while the per capita consumption of 131 gallons per day, with 25 percent of the services metered, was 13 gallons less than the 144 gallons per day estimated by Hill and Fuertes with the City on a fully metered basis.

In Boston in 1895, it was estimated that the population of the Metropolitan District was 985,000. Plans at this time were made for the construction of the Wachusetts Reservoir and the average per capita consumption of all the towns considered in this Metropolitan District was 83 gallons.

Mr. F. P. Stearns, for the State Board of Health estimated that there would be 28 cities and towns in the Metropolitan District, with a population in 1925 of 2,238,500, and that they would use 100 gallons of water per capita, making a total consumption of 224 million gallons per day. In 1925, there were actually 20 cities and towns supplied by the Metropolitan District, with a population of 1,400,000 and a per capita consumption of 98 gallons per day, and a total

water consumption of 130 million gallons per day, just a little over half of the total consumption estimated in 1895.

In 1903, in the report of Burr, Hering and Freeman on the additional water supply for the City of New York, it was estimated that by 1930 the total population in the Boroughs of Greater New York would be about 7 million, and that the per capita consumption at that time would be 150 gallons per capita, with a total consumption of 1,050,000,000 gallons per day. The total population of New York in 1903 was 3,780,000, and the total consumption of the City from the existing sources was 422 million gallons, or at the rate of 112 gallons per capita. Therefore the consulting engineers figured that the per capita consumption would increase from 112 to 150 gallons per day. By 1928, the population of New York had increased to 6,208,000 with a per capita consumption of 141.6 gallons per day, and a total consumption of 880 million gallons per day.

When we come to the smaller cities, the difficulties of estimating the future water consumption are even more pronounced than with the larger cities. In 1928, the average daily water consumption in the City of Frederick, Maryland, was 1,410,000, supplying a population of approximately 14,000, and giving the city a per capita water consumption of 100 gallons. The greatest monthly consumption during 1928 was during the month of August, when the consumption rose to 1,650,000 or at the rate of 119 gallons per capita. Frederick is practically an unmetered town and during 1930, with the hot dry summer and many lawns through the city to be taken care of, the consumption rose in July to about 2,650,000 gallons, or an increase in two years, of a million gallons per day. It finally became necessary to place restrictions on the use of water for sprinkling lawns and flower beds and streets, for washing cars in the garages, and this cut the consumption in Frederick almost a million gallons or back to about where it was in 1928.

With regard to future predictions of the amount of water required for a city's water supply, we feel that engineers are thoroughly justified in making liberal estimates. There are so many unforeseen conditions which arise over a period of thirty years more or less that the changes in consumption may be up or down. Fortunately for most of the cities during the past thirty years, the trend has been down, due largely to the fact of the increased use of meters and also to the fact that much more attention is being paid to underground leaks. Boston's water supply requirements in 1895 were greatly overestimated for the period from 1915 to 1930. The only effect of

this was that the Metropolitan Water Board was able to postpone large capital improvements for a period of fifteen years. In Baltimore, the estimates of Messrs. Freeman and Stearns for 1930 were quite accurate, although in the period around 1918 to 1920, as a result very largely of the tremendous war activities in and around Baltimore, the water consumption had taken a great jump. With a tapering off of the effect of the war, the water consumption in Baltimore has been held practically steady as to total quantity used, although the city has continued to grow in population, but not as rapidly as was forecasted by Messrs. Hill and Fuertes. Had the water consumption of Baltimore grown at the rate predicted by those engineers, Baltimore City, during the past drought year, would have been perilously close to a water famine. The raising of Loch Raven Dam, completed about 1920 and increasing the available storage from 2 to about 23 billion gallons, was a step that has saved the City a serious water shortage, as, during the past year, the storage in Loch Raven Reservoir was pulled down to about one-half of its capacity.

A factor of safety is used in making practically all engineering computations. In our estimates of the Albany water supply, where the new Alcove Reservoir provides an available storage of 12 billion gallons, we estimated that during the driest period that had occurred previous to 1927, with a draft of 30 million gallons of water per day from this reservoir, there would have been left in the reservoir, over 3 billion gallons of water, and these 3 billion gallons, capable of supplying the city for 100 days, were the factor of safety which we used in designing the Alcove Reservoir. This extra amount of water would take care of an unexpected growth in population or unexpected uses for industrial purposes or for drought periods of greater severity than any which we considered in making our original computations. We feel that, in water supply computations, an engineer is thoroughly justified in providing some factor of safety in studying the water supply, just as he provides a factor of safety in other engineering computations.

This paper might be extended to consider the fluctuations in demand for water over hourly, daily, weakly, monthly and seasonal demands. These fluctuations are of tremendous importance in the design of pumping stations, filtration plants, supply conduits and other features of water supply, but to attempt to go into them and give these various problems the consideration which they deserve would make a paper of this kind entirely too long.

HISTORY OF WATER SUPPLY WITH LOCAL REFERENCE TO BALTIMORE[1]

By James W. Armstrong[2]

When I was asked to present a paper before this meeting, I accepted with the intention of using a paper already prepared, which was presented before a company of preachers. In reading it over, I realized that preachers and water works men do not speak the same technical language. The title was chosen with the idea of counteracting the impression still prevalent in the minds of some people that water is a natural product and that they should not in any way be restricted in the use of it. The thought was fostered by two incidents, the first of which occurred a number of years ago in New Orleans, where, before the days of filtration, all the drinking water was collected from the roofs of houses and stored above ground in wooden cisterns. On one occasion I noticed a $\frac{3}{4}$-inch pipe discharging full capacity upon the ground and running to waste. A number of people were standing around, but no one paid any attention to it. At last I spoke to a boy calling his attention to the water being wasted and asked him to cut it off. "Oh," he replied, "that is not cistern water and makes no difference, that's river water." The other incident occurred in Baltimore a few years ago when a man running for mayor of the city told the citizens of Baltimore in his campaign speeches that water should be as free as the air we breathe, and if he were elected mayor everybody should have it free. Even those of us who have been for years engaged in furnishing and purifying water may not realize the great privilege that is ours in having an abundant supply of pure water. In order to show more clearly the transition that has taken place in modern times, some of the facts relating to the early history of water may be of interest.

WELLS

The first water works developed by man were unquestionably wells. Many examples of the work of ancient nations along this

[1] Presented before the Four-States Section meeting, April 1, 1931.

[2] Engineer of water filtration, Bureau of Water, Baltimore, Md.

line remain until the present day. The wells dug by Isaac and his struggles with the Philistines to keep them, indicate the value placed upon them by the early inhabitants of Palestine. Jacob's well at Sychar is known throughout the world and is in existence today. Perhaps the most famous well left to us by the ancients is Joseph's well located in Cairo, Egypt. It is sunk through solid rock to a depth of 297 feet. For the first 165 feet it is 18 by 24 feet and the rest of the way it is 9 by 15 feet. Water was lifted by means of endless chain buckets that were operated by mule power. The mules performed their work in a chamber that was carved out of the rock at the bottom of the first shaft, to which they had access by means of an inclined plane following the perimeter of the well. Many extensive storage reservoirs were built by the ancients. One in Egypt called Lake Maeris was built for storing waters of the Nile. This reservoir had a water surface of about 30,000 acres or about twelve times the area of our Loch Raven Reservoir. When the British took control of India there were 50,000 reservoirs in the Presidency of Madras, the construction of which required 30,000 miles of earth embankment.

AQUEDUCTS—JERUSALEM, ATHENS, CARTHAGE

As cities increased in size the difficulty of securing an adequate and suitable water supply also increased. In spite of limited knowledge, great difficulties were overcome and many of the ancient cities had a large supply of good water. In Jerusalem, there were many underground cisterns for the storage of water. There were pools and reservoirs which were fed by water brought into the city from outside sources through underground conduits. Some of these works were built by King Hezekiah about 735 B.C. and are described in "The Second Book of Kings." Water was brought into the City of Athens through conduits. All that is left today of ancient Carthage, at one time the rival of Rome, are the underground cisterns or reservoirs and a portion of an aqueduct supported on masonry arches, which brought water into the city from the Zaghoun Mountains, a distance of 60 kilometers. It seems incredible that such a vast amount of work should have been done for the small volume of water that was brought into the city, as the conduit conveying it was only about 10 inches square.

ROME

Of all the ancient cities, Rome probably had the best water supply. Before 312 B.C. water was used from the River Tiber and from

wells and springs in the vicinity, but as they became polluted Rome went to distant sources for its water. The first great aqueduct for conveying water into Rome was the Aqua Appia which was built 312 B.C. and was 11 Roman miles in length. Additional aqueducts were built from time to time for over 600 years. About 300 A.D. the city had a total of about 359 miles, 50 miles of which were supported on masonry arches. As far as possible, all the aqueducts were built on levels approximating the hydraulic gradient, following closely the contours of the hills. Where that could not be done the hills were tunnelled through, and in crossing valleys and ravines the aqueducts were supported upon masonry arches. Sometimes as many as three tiers were superimposed one above another.

Wherever Romans went they built aqueducts, using the same methods of construction that were employed in the vicinity of Rome. Ancient writers have told about many of the cities in which these aqueducts were to be found, and one of the more modern writers expresses the belief that there are some 200 relics of aqueducts to be found outside of Rome. Strange as it may seem, the best aqueducts were not built in Rome, but in the provinces governed by the Romans. One of the most notable examples left to us today is the historic aqueduct of Pont du Gard near Nimes, France, which is about 150 feet high and consists of three tiers of arches. It was built shortly before the birth of Christ, and is in an excellent state of preservation today. Another famous aqueduct is that at Segovia, Spain, which is built of most excellent masonry. It is about 100 feet high and it, too, is still in good condition.

Distribution system

There was no distribution system in Rome such as we have today, but water was first led to a large tank or cistern called a Castellum, and from there it was distributed to smaller tanks for public and private use. Most of the water delivered to the city was intended for public use and the citizens had to secure their supply from some of the public cisterns or fountains. There were, however, many of the rich and those who had the favor of Caesar, who had private supplies. Some of them had magnificently appointed baths as may be seen from the following as related by Frontinus:

"Seneca, having gone on a visit to the villa, then some two hundred years old, of Scipio the greater, at Liternum, in Campania, was astonished to find how simple, plain, bare and dark the bathing rooms were. 'Who would be content with such at the present day?' says he. 'Who would not consider himself a beggar if he bathed in a room whose walls did not shine with the fire of jewels;

if the marble of Egypt were not inlaid with the marble of Numidia and panelled with mosaics; if the ceiling were not wainscoted with crystal; if the tanks were not carved out of Parian marble; if the water did not flow from silver faucets? And yet I am speaking only of the baths of the people; what shall we see when we come to those of the select? What statues! columns, which have nothing to support, and which are there only for ornament! What masses of water falling in cascades with a loud noise! We have reached such a refinement of luxury that our feet may not tread upon anything but precious stones.'"

In Rome at the time of Constantine, there were 11 thermae or large hot water baths, 925 baths, 1212 public fountains and 247 reservoirs.

MEASUREMENT OF WATER

When a permit was granted for water, the size of ajutage or orifice was specified and the law prescribed the size of the outlet pipe which was required for the first 50 feet. No enlargement of the pipe was permitted at any point less than this distance from the outlet.

LEAD PIPE

The only metal known to the Romans from which they could make pipe was lead and they used great quantities of it in their distribution system. Sections as large as 27 inches in diameter and $1\frac{1}{4}$-inches thick have been discovered. The Romans were acquainted with the use of the inverted siphon as they were found in use in many places throughout the city. In view of their knowledge and extended use of lead pipe, it is a source of wonder that they did not bring the water across the valleys in lead pipes, which could have been laid in underground conduits at a small fraction of the cost of the masonry arches upon which the aqueducts were supported. Neither Frontinus nor Clemens Herschel, who comment upon the matter, seem to have given any clear reason.

In the light of some of the troubles recently experienced at Montebello with the lead lining of our alum boiling tanks, it has occurred to the writer that the reason the Romans did not use lead pipe for their aqueducts may have been due to its peculiar properties. Lead has a coefficient of expansion about three times that of steel, and once having expanded does not contract with a drop in temperature. It has very low resistance to bending and is entirely unsuitable for use in any structure where there is a reversal of stresses, as a few reversals are sufficient to cause a break, which in the case of an aqueduct means a leak.

FRONTINUS

Most of our knowledge of the water works of ancient Rome has come down to us in a volume written by Julius Frontinus, who occupied the position of Water Commissioner of Rome for a period during the last half of the first century. A translation of this book by an eminent American engineer, Clemens Herschell, contains much of human and technical interest. Among other things, he tells of the maintenance of the aqueducts by two gangs of slaves; one gang composed of 240 men paid for by the State and another gang of 460 men paid for by Caesar. A large part of his trouble was due to special privileges and graft. He was evidently proud of the fact that he was able to double the water supply of Rome by stopping leaks and cutting off fraudulent uses of water. The following is quoted from his book:

"This mode of gaining money, practised by the water-men, is also to be abolished: the one called 'Tapping.' Far away, and in all directions, run the pipes under the city pavements. I discovered that these pipes were furnishing water by special branches to all whom they passed and who had been able to arrange for it; being bored for that purpose here and there, by the so-called tappers; whence it came, that only a small quantity of water reached the places of public supply. The amount of water gained in consequence of our abatement of this evil, I measure by means of the fact that we have gathered a large quantity of lead by the removal of that kind of branch pipes."

MIDDLE AGES

After the fall of Rome, many of the aqueducts were destroyed and others gradually fell into disuse, until in some communities during the middle ages the residents did not even know for what purpose they were built. Unfortunately the church at that time taught that bathing was a luxury and therefore should not be indulged in. The people soon followed the teaching of the church and stopped taking baths. All sanitary precautions were neglected, garbage and refuse were thrown into the streets, so that the sanitary condition of the cities and streams became almost intolerable. The Black Death, which made its first appearance in Europe in the 14th century, carried off in successive epidemics over 40,000,000 people. The people became weakened and more and more anemic. In London in 1665, which was then a city of about 200,000 the Black death carried off 65,000 people in a single epidemic. It was these terrible epidemics that roused the people to the necessity of better sanitary conditions.

LONDON AND PARIS

Advancement toward modern water works systems has been exceedingly slow. Paris and London were leaders and their experiences may be considered typical. Paris at first depended on the River Seine for its water supply, but in 1183 reservoirs were built for impounding spring water which was conveyed to the city by a lead pipe which was still in service in 1878. This system furnished the citizens one quart of water each per day. Until about 1888, the total supply of the City of Paris amounted to only about 2½ quarts of water per capita. The first pump in London was located on London Bridge in 1582, and was operated by means of the current of the river. It was not until 1613 that London built its first aqueduct for bringing water into the city. It consisted simply of an open ditch about 38 miles long and was called the New River. With improvements in alignment and construction it is still one of the aqueducts supplying London with water. It was not until 1619 that the New River Company was incorporated for the purpose of laying mains through the streets of London for supplying each house with water.

MODERN WATER WORKS

No water works in the modern sense was possible until the advent of the steam pumping engine and cast iron pipe. Steam was first used for pumping water in London in 1761. The first distribution systems were made of lead pipe, which were obviously of little value except in small sizes. The pipe laid later was generally made by boring holes through wooden logs. Cast iron pipe did not come into use until about 1800. In 1804 Philadelphia laid the first cast iron pipe in this country and the next year Baltimore followed her example.

PERSONAL EXPERIENCE WITH OLD CAST IRON PIPE

I had some experience with early cast iron pipe. Just south of New Orleans there was an old sugar plantation which later became the Battlefield of Chalmette, and is the spot where Jackson won the last victory of the War of 1812. A small water works distribution system had been laid around the plantation with pipe reputed to have been brought from London nearly a century before. This piping was dug up and proved to be much heavier than modern pipe of the same size and was in such a good state of preservation that it was relaid.

EARLY FILTRATION

In the early part of the 19th century, some small filters were installed in Paris for purifying water taken from the Seine, but filtration on a large scale was not undertaken until 1829, when James Simpson designed and built a number of slow sand filters for purifying a portion of London's water supply. The design of early slow sand filters in the United States was predicated upon European practice. Before 1900 no large mechanical filters had been built, but there were many of the steel pressure filters and gravity filters of the wooden tub type in service. Those equipped with mechanical rakes for agitating the sand during the washing period were very satisfactory, but the change in shape of filters from round to rectangular, prevented the further use of mechanical rakes. The first large mechanical filter plant to be built in this country was designed by Mr. Charles Hermany for Louisville. The plans embodies some excellent features, but owing to certain mechanical defects, the filters were not the success the designers anticipated, and as the type was never copied, the good points were lost with the bad. In the year 1901, the one in which Louisville was started, a contract was awarded for the construction of the Little Falls Plant, which was designed under the direction of George W. Fuller. The little Falls Plant may justly be considered the prototype of the modern mechanical filter.

BALTIMORE HISTORY

Before taking up the details of Baltimore's water supply, it may be interesting to know that Baltimore's first water works was a spring located on Calvert Street somewhere between Center and Lexington Streets. In 1797 the City Council appropriated $1000 to erect and regulate pumps in the city streets. There was much agitation at this time for a better water supply and in 1804 a private company was organized for building water works. The first mains laid were of logs with 4-inch holes bored through them. Some of you may have seen specimens of these early pipes. As I stated before, Baltimore was one of the first cities in the United States to use cast iron pipe, some of which was laid in 1805. The first reservoir was located on the southwest corner of Calvert and Center Streets, and water was led to it from Jones Falls through an open canal from which it was lifted by a water wheel. In 1854, Baltimore City purchased the

property of The Baltimore Water Company, and about that time Lakes Roland, Hampden, Druid, and Pimlico, and the conduits connecting them were built. This water soon became polluted and further agitation occurred for securing a better water supply.

Gunpowder supply

The year 1881 marked the completion of the first Gunpowder River Improvements, which were built at a cost of $4,500,000. Lakes Clifton and Montebello and a tunnel seven miles long and 12 feet in diameter were put in operation. As most of you are familiar with the recent Gunpowder Improvements, I shall not attempt any description of that work as far as construction is concerned. I should, however, like to call your attention to the care and treatment of that water before it is delivered to the citizens of Baltimore.

Changes caused by raising dam

The present Loch Raven Dam forms an impounding reservoir covering 2500 acres and holding 23,000,000,000 gallons of water. The impounding of this water; in itself, has worked a number of interesting changes in the character of water delivered to Montebello. The river used to be very flashy; one day it would run clear and the next day it might look like mud. Turbidities as high as 5000 p.p.m. have been recorded. Most of the suspended matter carried by the small streams flowing into the reservoir is now precipitated very shortly after entering the larger body of water. As a result the water reaching Montebello is not subject to sudden fluctuations in quality and is much clearer than formerly. The water is also much freer from bacteria as great numbers of them are carried to the bottom of the reservoir with the sediment. In the old days they would have been delivered directly to the consumer without any extra charge.

The deep water at Loch Raven has had the effect of keeping the water delivered to the mains cooler in summer. On account of the unusual weather this year it reached a maximum of 70°F., but heretofore 66°F. has been about the maximum temperature. In one respect the large reservoir has been a detriment. It has proved a splendid breeding place for microörganisms.

City land

The City owns 8000 acres of land in the vicinity of Loch Raven and has absolute control of 50 miles of shore. Hundreds of thousands of

trees, mostly white pine, have been planted in this area and wherever trees are not planted, the fields are covered with grass. This covering of the ground has prevented erosion of the soil and has kept thousands of tons of sediment from our drinking water that otherwise would have required removal at the filter plant.

Sanitary control of watershed

The watershed which supplies the Loch Raven Reservoir comprises about 306 square miles, and covers a very large part of Baltimore County and a slight portion of lower Pennsylvania. For a number of years we have had an inspector whose entire time is devoted to the purpose of trying to prevent pollution of our drinking water. Every premise in the entire area is supposed to be inspected at least once every year, and villages that are located along the streams are visited as often as may be necessary. Every typhoid case on the watershed is watched to see that there is no danger of polluting any streams tributary to Loch Raven. In the last ten years very much has been accomplished in the way of abating sources of pollution and keeping impurities from the city water supply.

Copper sulphate

The large volume of clear water moving at slow velocity and a number of shallow places in Loch Raven Reservoir makes it an ideal place for the propagation of certain kinds of microörganisms, some of which, such as algae, are very objectionable as they impart a very disagreeable taste and odor to the water. Other higher forms such as cyclops and daphnia sometimes come down upon us in such numbers that they greatly shorten the filter runs by choking the sand beds. Other organisms adhere to the sand grains causing them to stick together, thus reducing the effective area of the filters. It is well known that copper sulphate in small quantities will kill most of the microorganisms, but on account of the great area of Loch Raven Reservoir, systematic treatment of the water was never undertaken until this year. Beginning early in the spring, all the coves were regularly treated and as a result our filters are in better condition this fall than formerly.

Pumping station

There are twelve different pumping stations employed in supplying the citizens with water. One of these, the low lift station at Monte-

bello, handles the entire volume of water consumed by the city. Others are distributed throughout the vicinity at different locations and are used for lifting water into the middle and high level zones. With the exception of Mt. Royal Pumping Station, which contains a large vertical triple expansion engine, all the stations are equipped with electrically operated centrifugal pumps. Mt. Royal will soon be replaced by the new Vernon Pumping Station which is being erected at the foot of the embankment on the east side of Druid Lake.

Volume of water used

Last year the City used an average of 114,340,000 gallons of water per day. This year, on account of the necessity of restricting water due to the drought, we expect the rate to be somewhat lower. The maximum pumpage for any one day in the history of the Water Department was reached last July when we pumped 144,000,000 gallons. This water would fill a pipe line 4 feet in diameter and 290 miles long.

Manufacture of alum

A little over two years ago when the new filters were first put in operation, the Bureau of Water Supply started upon a manufacturing program. Before that time they had purchased alum under contract of about 2000 tons each. When the new filters were built an equipment was installed that enabled the city to manufacture its own alum. The process of making alum is a very simple one. It is made by mixing together in the proper proportions sulphuric acid, water, and bauxite. Bauxite is a clay very rich in aluminum and comes to us from Arkansas, burned, dried, and ready for pulverizing. The manufacturing equipment is so designed that no manual work is required for the lifting of chemicals. Everything is handled by machinery operated by electric motors, remote controlled, and is actuated by push buttoms. With our equipment it takes less labor to make liquid alum than it formerly did to dissolve the lump alum that was purchased under contract. The saving effected by making alum has been very great. Prejudice against the use of alum has almost died out, but that some of it still exists is shown by a little incident that happened not so long ago. A woman came to me and said that her lawn was not looking well. She said she had been sprinkling it thoroughly and still the grass was drying up. She was sure it was due to the alum we put in the water. She had frequently seen our

big truck pass her house loaded with alum and therefore thought she had some reason for her statement.

Lime treatment

In every large city there are many industries that are vitally affected by the quality of the city water. Unfortunately, the kind of water required by one industry is often harmful to another. For some purposes soft water is desirable and for others hard water is desirable. For instance, laundries prefer to have a soft water as it takes less soap and the clothes are cleaned more easily. In boiler plants it is also desirable to have soft water to prevent encrustants from forming on the boiler tubes. Soft water, however, is corrosive to iron and steel and as there are millions of dollars worth of pipe in the streets and buildings of the city, its preservation becomes a problem of major importance

It is obviously impossible to treat the water in such a way that everybody will be pleased; consequently, a treatment is employed that serves the most people in the best way. For Baltimore the most important phase of water treatment, aside from its purity, is to keep it slightly alkaline in order to prevent corrosion. For this purpose from one-half to three-quarters of a grain of lime is added to each gallon of water just after it leaves the filters. The exact amount of lime to be added is determined by the hydrogen-ion concentration of the water or pH value as it is usually called. We have a Leeds and Northrup instrument for determining this, which is in reality a very sensitive volt meter which records accurately 0.0025 of a volt.

Distribution of water

The question is often asked how the water is forced into the City. The water surface of the filtered water reservoirs is about 213 feet above the level of the bay and water flows from these reservoirs by gravity to all the lower portion of the City, which consumes about two-thirds of the water filtered. There are two other zones; middle zone which is supplied by such reservoirs as Ashburton and Guilford, and the high zone which is supplied by Towson and Pikesville Reservoirs. The Water Department of Baltimore has laid throughout the streets and in the adjacent counties about 1400 miles of water mains.

Distribution reservoirs

The water on leaving the filters enters the filtered water reservoirs at Montebello, of which there are three. From these the water is

pumped to the various distributing reservoirs located in Baltimore and vicinity. Pikesville, which is about 9 miles out on the Reisterstown Road, is the most remote and the highest in elevation, its water surface being maintained 565 feet above the bay. These reservoirs are all of the open type. Frequent careful analyses are made of samples taken from each of these reservoirs and they are regularly treated by the application of hypochlorite of lime, in order to insure the delivery of sterile water into the mains.

Gauging stations

In every large city the problem of meeting new demands for water is a never ending one. History is constantly repeating itself and no sooner is one supply completed than engineers are looking about for the next possible source. For years the City of New York has constantly been working on the problem of new supplies. Keeping New York supplied with water is probably the largest engineering problem ever undertaken in America. Baltimore in a lesser way is looking to the future, and in order to know with certainty the value of some of the streams in its vicinity as a potential water supply, we have established two gaging stations on the Patapsco River; one on Little Gunpowder Falls and another on Deer Creek. The City builds and maintains these stations, but they are operated in conjunction with the United States Geological Survey who make the gagings and keep the records. As you all know, Baltimore is now building a large masonry dam on the Western Branch of the Gunpowder River that will give 20,000,000,000 gallons additional storage, but in order to be safe the City needs to go to another source. They have already petitioned the State Legislature for authority to issue bonds for this purpose to the extent of $35,000,000.

Laboratory control

In order to insure the delivery of a good quality of water to the citizens of Baltimore, samples are regularly tested from the plant at different stages of the purification process. Samples are also tested from Loch Raven from each of the distribution reservoirs and from different taps located at widely separated points in the city. During 1930, the laboratory force made over 12,000 bacterial tests, and about 15,000 chemical determinations. In order to do this they put up 65,000 tubes of lactose broth. We keep busy six days a week,

with the exception of holidays, a laboratory force consisting of three chemists, two bacteriologists, two cleaners.

1930 drought

During the early part of 1930 we had an abundance of rain. The result was that the stream flow was greater than the consumption in the city until July 1st when the water fell below the crest of the dam and steadily dropped until December 26 when it was 15 feet out. Since then gentle rains have brought the water up until it is only about 9 feet below the crest of the dam. A decided effort has been made to conserve water and apparently the city is now using about 10,000,000 gallons less per day than we did at a corresponding period a year ago. As a precaution, the city purchased an 8-inch centrifugal pump and we are reclaiming the wash water which formerly went to waste. In this way we are saving an additional 2,000,000 gallons per day.

DISCUSSION

S. M. Van Loan:[3] The reference of Mr. Armstrong to Baltimore history relative to its early water supply mentions the year of 1797. Paralleling this date in Philadelphia there was a petition presented to the City Council urging the introduction of water for the use of its residents.

Reading of the early settlement of Philadelphia there is mention of "great prudence and wise forethought" as regards a water supply and the early text refers to a Gneiss rock strata which lay below the surface covered by a layer of water bearing gravel and sand above which a clay deposit was formed.

Reference further points out the value of this sand and gravel as a natural filter and that wells could be sunk therein giving a supply of a potable and clear water.

As the population of the City increased, the residents adopted means of providing for local sewage in the shape of cess pools.

This system destroyed the virtue of the subterranean waterways and the City was compelled, after 100 years of use, to abandon them and seek their water supply in sources of streams.

During the year 1793 the City suffered a very serious and virulent epidemic of typhoid fever, and it was during 1789 and preceding ones that Benjamin Franklin had urged upon the City the use of

[3] Deputy Chief Engineer, Bureau of Water, Philadelphia, Pa.

water taken from the Wissahickon Creek, a stream that entered the Schuylkill River some 13 miles above its entrance to the Delaware river.

Unfortunately Benjamin Franklin died in 1790 and no later efforts were made to pipe the water from the Wissahickon Creek to the City of Philadelphia.

It was his thought that a dam could be constructed thereby giving ample supply and head for use in Philadelphia. Following the petition of Council in 1797 there was in 1798 a report submitted by a distinguished engineer and architect, Benjamin Henry Latrobe, on a water supply for the City.

The question had been considerably agitated after the suggestion made by Benjamin Franklin. Coincident with the activity for a water supply was a general movement towards canal transportation throughout the East in Pennsylvania. In other words, the Inland Waterways was considered an economic and progressive movement and among the schemes propounded was one to connect the Delaware and Schuylkill rivers somewhere above the old City proper.

There was an old run on the Delaware river above the present location of Vine street and on the same street, projected to the Schuylkill banks, there was another run extending easterly from the Schuylkill. The thought was to connect these two runs and form a canal between the rivers and the canal so built would afford a means of obtaining water for the consumers and land adjacent to the banks.

The methods followed would be to extend pipes from the canal banks below the water surface to supply private cisterns and public fountains and the only reason apparently that this canal and alleged reservoir was not built was due to the lack of an agreement between the Canal Company and the City as this project of construction was in the hands of a corporation called The Delaware and Schuylkill Canal Company.

When Mr. Benjamin Latrobe was commissioned by City Council to investigate sources of water supply, there were four that he took into consideration:

1. To complete the canal; but he did not push this recommendation due to fear that ice would embarrass the winter supply for culinary use and that it could not be made immediately available.

2. To conduct the water from the Wissahickon Creek. He regarded the stream as insufficient and that it had almost frozen to the bottom on several occasions. Apparently they lost sight of the

Franklin suggestion of a dam, inasmuch as this source of supply would have taken water from a watershed of 44 square miles and afforded a daily contribution of 60 million gallons.

3. To erect water works to be driven by one of the two rivers. Mr. Latrobe did not favor this project, due to the experience of London and Versailles, where the operation of water wheels was frequently suspended due to the change in tide and with fires raging at such a time there would be no water.

4. To collect water in impounding reservoirs from any practical source and bring it through iron pipes to the City. This fourth scheme was considered uneconomical and that water should not be brought from a source one yard further than was necessary.

Following an analysis of these four projects he proposed a reservoir in Center Square, the water to be pumped from the Schuylkill and raised in the City reservoir by steam. This formed the basis on which the first City Water Works were built, but a modification was made and it was planned and the construction that followed was to erect a steam pump at a point on the Schuylkill where the present Chestnut street crosses. Two basins were built of masonry, one of which was connected to the river by means of tide lock gates. From the second basin a subterranean tunnel connected to a shaft or well 40 feet deep from which a steam pump forced the water through a 6 foot brick tunnel to the Center Square location where it was repumped to a tank of such elevation as to give pressure throughout the area which it was to serve.

The pumping station at the Schuylkill river terminal had a capacity of 1½ million a day and the pump at the Center Square, the other terminal, could raise daily one million gallons.

The tank built on the Center Square Works contained only 17 thousand gallons which records showed could be filled in 25 minutes and emptied in an equally short period. This required constant pumping and was unsatisfactory as the consumers made many protests about the inability at times to get water and that they had to revert to the pail and dipper from the wells.

These works operated until close to the year 1815 when the development of the Fairmount Works was started. During this period from 1800 to 1815 many feet of wooden pipe were laid for distribution needs and even until 1832 wooden pipe was installed, there being, at the latter date, a total of 240,000 lineal feet of wooden pipe in the City streets, the largest of which had a 6-inch bore.

The engine erected in the Center Square Works was of novel and interesting design. The lever beams, fly wheel, shafts and arms, cold water pumps were all of wood and the boilers were wooden boxes made of 5-inch white pine plank. Fire box was of wrought iron with vertical flues of cast iron. The main steam cylinder was cast in two pieces united by copper.

The Fairmount Dam, after considerable controversy, was started and completed in 1822. This pumping plant operated under water power and supplied a reservoir constructed upon adjacent territory and continued to supply the City with water until 1845, when a second pumping plant, operated under steam power, was constructed on the Schuylkill close to a mile from the Fairmount Dam.

MEETING EMERGENCY DROUGHT CONDITIONS IN SANTA BARBARA, CALIFORNIA[1]

By V. E. Trace[2]

The waters supplying the inhabitants of the City of Santa Barbara are derived from storage of flood waters on the Santa Ynez River and water developed in tunnels into and through the Santa Ynez Range. One of the tunnels is 5,080 and the other is 19,560 feet in length; the latter is for the purpose of diverting water from the Santa Ynez drainage basin to the City of Santa Barbara.

In 1919 Gilbraltar dam was constructed across the Santa Ynez River at the point of diversion to impound flood waters. The reservoir created by this dam has a capacity of 14,000 acre feet and a drainage area of 208 square miles. The storage water obtained from this drainage area is now the main source of supply for our city.

In March, 1928, the storage reservoir was just filled to its capacity with very little water wasted over the spillway. The year 1928 marked beginning of the drought period; the rainfall was below normal and there was very little or no runoff. Consequently, the supply was depleted during the following drought years.

The available supply in storage in 1929 was 12,000 acre feet; in 1930, 8,500; and in 1931, 3,800. In the latter year the supply, after deduction of loss from evaporation, was less than the requirements, and this necessitated the development of other resources and the curtailment of water consumption.

Notices were mailed to all water consumers to guard against the waste of water by careful irrigation and sprinkling of lawns to prevent the waste of water into the gutters of the streets; (2) to keep plumbing and water fixtures in good repair; (3) to eliminate washing of sidewalks and driveways when a broom would do as well; (4) to turn off all faucets when not in actual use; (5) to eliminate the waste of water in washing vegetables under a stream of water when they could be cleaned as effectively in a pan of water.

[1] Presented before the California Section meeting, October 30, 1931.

[2] Superintendent, Water Works Department, Santa Barbara, Calif.

It is gratifying to state that the consumers in general responded to the request to the extent of a decrease in the water consumption in excess of one million gallons per day, which postponed the time of the depletion of the supply. The time of exhaustion of this supply has been further extended by the development of underground resources within the limits of the city.

This new underground supply developed a production of approximately 3,000 gallons per minute. The supply from this source proved to be as great as anticipated, but the quality of the water was unsatisfactory. Analysis of water taken from this source showed the hydrogen sulphide content to be as high as 12 p.p.m. and it was necessary to install aeration equipment to take care of this condition.

Should this drought period continue another year, as is now anticipated by the Scripps Institution of Oceanography, La Jolla, California, the seasonal precipitation for 1931 and 1932 will be below normal. If this occurs and no runoff is accumulated, it will be necessary to develop further the underground resources of the city to meet the requirements until the end of the drought period.

THE ARTESIAN WATER SUPPLY FOR THE LATHAM WATER DISTRICT, NEW YORK[1]

By F. J. Keis[2]

The artesian wells furnishing water to the Latham Water District, Colonie, New York, are among the largest in the State. They are also somewhat unique because of their location between the Hudson and Mohawk rivers which are respectively 300 feet and 125 feet lower than the well sites.

The presence of artesian water was discovered about $3\frac{1}{2}$ miles west of Watervilet in the late nineties by engineers engaged in making test borings over a proposed canal route from the Hudson to the Mohawk river. The City of Cohoes interested in securing a new water supply then did considerable prospecting in the vicinity of the present Albany Airport, which lies at an elevation of 270 feet above sea level, and developed several wells. Some of them are still flowing and are being used by the Airport, Albany County Welfare Buildings, and Hospital. They have a static head of about 25 feet and a free flow of about 250,000 gallons per day. For many years they furnished water to the Shaker settlement which stood where the Airport now is and maintained service on the second floors of the community buildings without pumping.

My interest in this field was first aroused in 1906. In 1912 an opportunity was afforded to have the wells cleaned and placed in order for a test. They were found to be about 100 feet deep and seated without strainers into a shallow bed of gravel varying in thickness from 18 to 24 inches. The overlying stratum was mostly clay. The wells were pumped in rotation over a period of about three months and the effect noted on the other wells in the field. From these observations it appeared that the comparatively shallow water-bearing stratum should not be developed for much in excess of two and one-half millions of gallons per day. We were, convinced, however, from geological data and our investigations that deeper deposits

[1] Presented before the New York Section meeting, April 23, 1931.

[2] Consulting Engineer, Troy, N. Y.

of gravel existed and that we had but to locate them in order to develop a much larger supply.

Because of the limited funds then available for prospecting we were prevented from continuing our work and nothing further was done until last year.

It might be of interest to review briefly the geology of this area. The artesian field so far developed lies between the Hudson and Mohawk Rivers at an elevation of about 300 feet above sea level. The static level of the water in the Lathams wells is 315 feet. Geologists tell us that this section of the country was covered by the great Wisconsin ice sheet which reached as far south as the island of Manhattan. This ice was of such immense proportions that it passed completely over the Adirondack and Catskill Mountains and filled the pre-glacial valleys of the Hudson and Mohawk rivers. The equilibrium of the earth's crust was disturbed by its weight and great areas were alternately raised or depressed by the ice burden. The old Mohawk channel is supposed to have extended easterly from Schenectady and to have discharged into the Hudson at Albany. Another important valley extended from this one, northerly, and more or less parallel to the Husdon up to Round and Saratoga Lakes.

The ice in its movement transported great quantities of soil, boulders, and gravel. Bed rock was ground to flour to form many of our green, red and blue clay deposits.

Eventually the climate changed, the ice began to melt and immense volumes of water flowing seaward formed a great lake known as Lake Albany. It covered, Albany, Troy and Schenectady and extended as far as the Hoosic River. Then in turn the water began to recede, the Mohawk had deposited so much material in its delta that its outlet into the Hudson Valley became closed. The water then broke through to the north at Schenectady and flowed up through Ballston Lake and Saratoga Lake to make one of its principal outlets to the Hudson through Round Lake and the Anthony Kill at Mechanicsville, some 12 miles north of Troy. Then as the flow diminished it wore its way over the rock barrier extending from Aqueduct, near Schenectady, to Vischers Ferry 5 miles east of Schenectady, and cut its present channel into the Hudson at Cohoes.

During the ice and subsequent melting periods great deposits of gravel, clay and sand were formed. The old Mohawk channel became filled as did the pre-glacial valley extending up through Round and Saratoga Lakes. At certain places the ice sheet persisted until

this huge deposition process had more or less ceased. This accounts for some of the large depressions in the topography such as now form Ballston Lake, Round Lake, Saratoga Lake, and the site of the Tomhannock Reservoir, now the source of Troy's water supply. On the other hand there were places where openings occurred through the ice and into these the glaciers deposited great volumes of material to appear later as hills in the terrain. These may be identified by the various and unrelated conglomerate that enter into their composition.

The gravel, boulders and coarse materials left in the pre-glacial valleys and eroded channels provided a passage way for the future ground waters. These coarser deposits were in times of more quiescent water covered by fine sediments which formed an effective seal from the surface.

It is in these situations where the gravel deposits are extensive enough and reach to sources of water at higher levels or are fed by underground streams under pressure that a good artesian field may be found.

Most of the rock in this vicinity is shale. It is usually folded with the strike north east and the dip to the east. There is little uniformity in the spacing of these folds, at some places they are very close, and at others considerable distances intervene. The crests sometimes extend above the surface, but often they are hidden and are frequently badly distorted. In any drilling operation for a water supply it is important to study carefully these folds as it is necessary to be clear of them in order to be successful.

THE LATHAM WATER DISTRICT WELLS

Our experience with the growth of the Latham Water District has been almost as interesting as the development of the supply. Lathams is a community of about 600 people located 4 miles west of Troy. In the fall of 1929 we were asked to organize a water district under the Town Law and build a small water system. Sixty-six thousand dollars were appropriated and plans were made for a well supply, with about 5 miles of 6- and 8-inch pipe in the distribution system and a 100,000 gallon elevated steel tank to afford 60 to 75 pounds pressure. It was determined to remain away from the vicinity of the Shaker wells, and after carefully considering the geology and history of the area we began drilling in February, 1930, near the place where artesian water was first found. The water bearing

gravel was located about 80 feet below the surface but was only a few inches in depth. It was overlain with blue clay and the first test well had a capacity of about 50 gallons per minute. Rock was found under the gravel and we decided that our location was on a covered fold. Three more holes were put down and our position with reference to the fold determined. Water was found in all four holes and each one had a small flow at the surface. These wells would have provided more than sufficient water for the District as organized, but we were confident that a larger supply was available. We were fortunate in our choice of drillers and they being quite as confident as ourselves, decided to proceed until we located a better gravel stratum. Another site was determined upon farther to the southwest and about 1 mile east of the Shaker Wells. Here the drill went through about 200 feet of blue clay, encountered a good supply of water in gravel, but as the site had been loaned to us for test purposes only we could not develop it. The drill was moved 400 feet to the east and here again penetrated about 200 feet of clay to find a thin layer of gravel and then rock. This hole like all the others discharged at the surface, but only a small amount.

We concluded that we were again back on the fold on which we started a mile to the north. We felt quite confident now of our position and purchased a site about 1000 feet to the west and resumed drilling. Six-inch casing was used for these test wells and was withdrawn after it had served its purpose.

After penetrating about 200 feet of blue clay at the new site the bit entered the gravel. A 6-inch stream rose into the derrick and showered the men with stones, mud and water. The tools were withdrawn and the flow was not checked until 20 feet of casing was added to the top of the well. The ejected gravel was well water worn and some of the specimens weighed as much as two pounds.

A 3-inch orifice was now connected about 4 feet above the ground and showed a discharge of 320 gallons per minute. The drill was worked into the gravel to ascertain its thickness, and after penetrating 20 feet we decided to proceed with the large well. The rig was moved 30 feet to the west and work was begun on a Layne-New York gravel barrel type well.

This well, 12 inches in diameter, was carried down into the gravel and 20 feet of shutter screen was embedded into it. It proved a success and an orifice gauging showed 340 gallons per minute.

Tests showed comparatively little interference with both wells

flowing and it was decided to place a 20-foot strainer in the bottom of the test well and retain it as a part of the supply. With both wells flowing the combined discharge is nearly 625 gallons per minute or about 900,000 gallons per day.

A pumping station was built between the wells and they were cross connected so that pumps may draw from either or both of them. Two horizontal motor driven centrifugal pumps have been installed, one of 400 and the other of 500 g.p.m. capacity. The larger is also equipped with a Climax gasoline engine standby. At a draft of 420 gallons per minute the gauge shows that the wells exert a 4 pound pressure on the pump suction and at 540 gallons, 3.3 pounds.

The equipment is automatically controlled and set to operate during hours of "off peak" load so that current is purchased at minimum rates.

The water is of excellent quality, with a temperature of about 40 degrees. It has no B. coli and the 24-hour count on agar is only 1. The hardness is 133 soap test, and the pH is 7.2. No treatment is used and no chlorine is added.

The question naturally arises as to why such large equipment was used for such a small system. When this fine supply became known, application for extensions to the Water District began to come in. First one of 4 miles on the Shaker Road, then another of 7 miles to Newtonville and Loudonville, followed by five more. The pumping station equipment was accordingly increased, the supply main was enlarged and the design changed from time to time almost overnight. Another 200,000 gallons elevated steel tank was added to the plant and this will probably be increased to 500,000 gallons. Fortunately the well site is strategically situated. The distribution system is somewhat like an elongated parallelogram with the wells near the middle of one side. Several roads radiate from the well site through this parallelogram and additional feeders may be laid as they become necessary.

From a small beginning of 5 miles of 6- and 8-inch pipe there have now been added or requests made for 30 miles more and the authorized and requested appropriations have been increased from $66,000 to $475,000.

The first pipe was laid in April, 1930, and service was begun in October. A comprehensive plan for future extensions has been worked out and what was originally intended to be a small community system now bids fair to become an important plant with real possibili-

ties for one of the most attractive residential sections in eastern New York.

While the District with its additions will not now utilize the full capacity of the wells, it is planned to drill another one so as not to tax them. This new well will be at a considerable distance from the present ones and in addition to acting as a reserve it will afford an opportunity to make further studies of this unusual field.

With an accomplished growth of 400 percent in a year, with requests now filed for extensions totaling 300 percent more and with possibilities for still others, the present plant does not seem to be even distantly related to the one originally planned. We have, however, with the coöperation of the commissioners, Mr. F. H. Austin, Chairman, Mr. Sylvester Denison, Treasurer and Mr. Harry D. Carlson, Secretary, been able to revise and rearrange construction and financial plans, establish service and keep the extension work going so as to make this excellent water supply available to a large part of the community lying between the cities of Troy, Albany and Schenectady, without practically any interruption.

The Contractors are, the Layne-New York Company on the wells, Barone Bros., W. G. Fritz Company and Frank G. Blair and Sons on the pipe work, and the Chicago Bridge and Iron Works on the Tanks. De Lavaud pipe with Leadite joints is being used for the mains and copper tubing for the services. The Eddy Valve Company and the Ludlow Valve Company are furnishing the valves and hydrants respectively.

INVENTORY AND STOCK CONTROL[1]

By A. J. Conaty[2]

This paper is a brief description of the accounting system of the Milwaukee Water Works. It might be well at the outset to inform you that our water utility accounts were revised by the Milwaukee Bureau of Economy and Efficiency, acting under the direction of the Common Council of the City of Milwaukee, having engaged Mr. John P. Tanner, Certified Public Accountant, to design a classification of accounts, blank forms, and accounting procedure, assisted by Mr. H. P. Hohmann, Superintendent of Milwaukee Water Works. This proposed accounting system for the water utility was approved by the Railroad Commission of Wisconsin on December 26, 1911, and has been in force all these years with very little change.

The several divisions of the water works making up our organization are shown below:

Superintendent of Water Works in Charge of Operation of the following Divisions:

Division	*Directing head*
Pumping	Chief Engineer of Power Plants
Purification	Chemist and Bacteriologist
Distribution	Superintendent of Distribution
Meter	Superintendent of Meters and Services
Collection	Chief of Collection Division
Stores	Keeper of Stores
Accounting	Chief Accountant

City Engineer in charge of new construction:

Construction-Distribution—In charge of Engineer of Distribution

Construction—Pumping Stations—Engineer in Charge of Design and Construction

Each of these divisions has summary accounts, subdivided as far as is necessary to provide desirable detail accounts in the General Ledger, employing in all nine summary accounts.

All purchases and authorized expenditures are made out in voucher form and recorded in a columnar Cash Disbursement Book as to

[1] Presented before the Wisconsin Section meeting, October 27, 1931.

[2] Chief Accountant, Water Works, Milwaukee, Wis.

voucher number, payee memorandum, classification debit numbers, amount of expense, with totals and miscellaneous items posted to general ledger and grand total of each page a credit to Accounts Payable. Work orders when appearing on vouchers are entered in remark column opposite voucher number and posted monthly. Payrolls are entered monthly under heading, "Charged from time Distribution," which must balance with total of monthly payrolls.

Time slips are provided for each division to report daily, name and time of each employee, together with description of work and hours of labor. This slip carries "Amount, and Charge To" columns, enabling the cost clerk to make daily distribution of the time to proper classified accounts or to such work orders as shown. An abstract is made of the daily time slips. A recapitulation blank is furnished to record daily time reports of the various division activities as to account numbers and work orders. Thus the posting of these to the distribution of time roll blank is rendered quite simple to check as to its accuracy. This blank carries 31 lines, one for each day in the month, with 25 blank columns. There is a total column to the right and a grand total column at the foot of the blank. Ledger account numbers are entered on bottom of blank for each work order and has a posting check for all account numbers at the bottom. Much the same system is used in the distribution of materials and supplies carried in stock.

Each division carrying stock has been in the general ledger a separate stock control account. This account being charged with the value of all goods received and materials and supplies out of stock are charged to the proper accounts through requisition on stock-keeper, executed in triplicate, showing quantity, size, description, weight, price and amount.

Detail stock ledger cards are maintained for recording the receipts and disbursements of the various materials and supplies, thus becoming a perpetual inventory on materials and supplies on hand at the end of each month. Cards are arranged in groups in cabinets as to certain materials charged to a certain stock account as shown by the classification of accounts. As materials and supplies are used and credited in general ledger stock accounts, corresponding detail entries must be made on the stock ledger cards. The sum total, as shown on the various detailed stock cards for any particular stock account must agree with the general ledger controlling account. The cost clerk makes working abstracts of all materials and supplies

received and disbursed, this being a check on the ledger stock cards balances.

The Stores Division is commonly known as the pipe yard. The Keeper of Stores is in charge of a Superintendent and Assistant Superintendent with two clerks and four laborers. Pipe, hydrants, castings, and fittings are received and stored here and the controlling accounts in the general ledger are pipe, fittings, hydrant and scrap. Suitable receiving and outgoing reports of material and supplies are furnished weekly to the general office together with a statement showing the kind and number of pieces of pipe, fittings, hydrants, etc., on hand at the close of each week. Outgoing material and supplies are only permitted to leave the yard on requisition to storekeeper, showing quantity, size, description, weight and price. A charge column shows work order number or bill number covering. At bottom of this requisition is shown issuing authority, filled by, and receipt for same, copy being furnished to the accounting department. Material returned to stock is reported on a special blank showing work order number, description of material, and from where.

Pumping Stations report monthly supplies on hand the first of the month, amount received and used, balance on hand at the end of the month. This covers approximately 22 articles of supplies, such as coal, oil, grease, waste, etc. Corresponding detail cards are in the general office. The cost clerk makes the distribution of this expense, charging the necessary classified accounts of the general ledger, such as steam supplies, lubrication, waste and packing, etc., and crediting the stock control accounts, the posting of which is done by the Bookkeeper.

The Utility makes and charges for all repairs to meters in the system, of which there are about 35 different kinds of meters. This necessitates carrying in stock an immense amount of parts. Detail cards are made out for each, showing the number and value at the beginning of month, parts received and used, and value at end of month. A daily report of material and supplies is furnished to the accounting division showing quantity, size, description, price, amount and charged to work order or account number. At the end of the month a distribution is made of the outgoing material, arranged as to maker of meter, description of material, assembled as to kind and priced. Credit is transferred then to cards and total of various makes agreeing with summary of daily reports of month credited to stock control in the ledger.

This same method is used by the Distribution Department for all

repairs, reported on consecutive numbered work orders for all material used in repairs to mains, hydrants and miscellaneous operations. All scrap sales must be reported on proper requisition showing weight and amount of sale with bill number covering and to whom sold.

At the end of the year each division is required to make a physical inventory of stock on hand as to number and description, and are priced by the accounting division. The difference between inventory, cards and ledger controls, if unaccounted for, is adjusted through journal entry. In stores, physical inventory valued at $352,000.00 required only a credit adjustment amounting to $14.46 in order to bring it into accord with general ledger control. Mains and meter stock required only a credit entry of $29.85 on stock inventorying $40,000.00. Besides the inventory of materials and supplies once a year, a complete inventory of assets are taken showing description, condition, quantity, date acquired, cost, present value on basis of going concern.

The original cost is carried in the statement of the value of assets so that the advantage of a current historical record of assets are not destroyed by the actually working off the wasting (or diminishing) value of assets. Recognizing that there is unquestionably a wasting value we have therefore an account known as "Depreciation (of used and useful property) not written off," in which to record an estimate of the wasting in value of our assets which cannot be (or is not) offset by ordinary maintenance expenditures.

Monthly trial balances are taken of the ledger accounts and a balance sheet drawn. At the end of the year the revenue and expenditures are closed out into Profit and Loss and a detailed statement for the annual report made of each division as to the various expenses incurred as classified in the general ledger, totals of which must agree with total expenditures. Comparative figures are obtained in detail by using the total pumpage as a devisor to find cost per million gallons pumped. Revenues are shown in detail in the different classes of consumers as required by the Public Service Commission of Wisconsin.

DISCUSSION

F. K. QUIMBY:[3] I feel that Mr. Conaty is to be congratulated on this paper and that we can all profit by Milwaukee's example of "Stock Inventory," if that term applies.

[3] **Construction Engineer, Water Department, Racine, Wis.**

It is probable that few of the water departments smaller than Milwaukee go into this phase of the work as completely as they do. Most of the departments probably do not have stock clerks stationed at the supply yard, nor do they file reports on incoming and outgoing material weekly. It is probable that material is reported "in" when it arrives and "out" when it is taken to the job. These systems, which each one of you have worked out to your own satisfaction, are a means to the same end that Milwaukee accomplishes so satisfactorily. You may or may not do it as well. I can speak for the Racine Department and say that when and if we check our physical inventory against our book inventory to as close a percentage as Mr. Conaty does, we will give our accountant a shock.

I should like to touch on the material reports for the several departments before I go to the matter I wish to emphasize, that of the stock control and reports of materials used in the water mains extensions and valve and hydrant installations.

All materials received in the department, whether for the pumping station, filter plant, meter shop or construction division, are reported to the office as received when the invoices are O.K.ed for payment by those responsible and are charged "out" as used, the reports coming in usually at the end of the month, unless that particular division reports materials by the job.

At the pumping station, oil, grease, rags, boiler compound, etc., are listed daily and reported to the office once a month. The method of buying coal is rather unusual, but more than satisfactory. The station is adjacent to a wholesale coal dock and the traveling crane overhangs our coal bunker. When our supply runs low the coal company fills up the bunker and is paid monthly as we use it and on our own weights. This saves the handling for weighing on the part of the coal company and the cost of tying up money in coal stocks on our part.

The materials such as alum, chlorine, ammonia, etc., for the filter plant are reported as used on each shift and tabulated each day and reported to the office each month.

The meter division charges material out on each job and not by the week or job. This department, with its innumerable small parts, seems to be the hardest to keep straight with the physical inventory.

Our department seems about on the dividing line between where a stock clerk is necessary for accurate accounting of materials and where we can justify the added expense. As it works out now the head of

each division is responsible for his materials used. Probably, if we installed the house services we would have to have a clerk, but it seems rather inadvisable just now.

Each major project of new work or equipment, whether pipe line extension, stand pipe, new pumping station, automobile or truck receives an "Authorization number" when authorized by the Board of Water Commissioners. In addition to this "Authorization number" each pipe line extension or authorization for extra hydrants or valves, receives an "Extension number." These numbers run consecutively from the time the plant was purchased by the City in 1919, and all materials and labor in their construction are charged to them. This is practically the same system used before the City bought the plant, but the City started out with a clean slate.

When a pipe line extension is started the foreman makes out a list of materials, from a sketch map furnished him, and orders these materials delivered to the site of the work. This material list is made out on a "material transfer memo" which will be shown on the screen later. The amount, size and other details are listed so the truck driver can make no mistake. This memo shows where matecial was taken from, delivered to, by whom ordered and delivered and also the authorization and extension number to be charged or credited. If any of this material is returned to the yard or taken to another job another of the same slips is made out showing the transfer. These slips are later checked against the final report and any descrepancies checked and corrected.

The final report is made on several sheets. One sheet shows weights of full lengths of pipe used and pieces of pipe taken from stock or cut in the field, also the lead, yarn and incidental materials, another the fittings, valves, etc., at intersections and the measurements to them, another shows material used in hydrant branches and another gives general data on construction having little to do with material. There is still another set of forms used in separate hydrant and valve settings, in short extensions, etc. where the materials used are few in number.

When these final reports are made to agree with the memo slips the material is entered on the stock cards. These stock cards are made up of three headings: material received, issued and unissued, and are carried from year to year with the entries made in the received column as invoices are received and in the issued column as the reports come in. The unit cost, you will notice is carried along

with incidental charges for drayage, etc., included to make the cost complete for material in the yard. These cards do not make a perfect perpetual inventory as the reports are of necessity made up after the material has been out of the yard for some time.

General inventory is taken in each division as of December 31, each year and where unreconcilable differences occur they are charged to profit and loss. I cannot tell you right now what these differences have been in the past, but they have been well within reason.

NOMOGRAM FOR THE EVALUATION OF pH, ALKALINITY AND CO_2 IN WATER

By I. Laird Newell[1]

The use of alignment charts or nomograms for the evaluation of engineering data is well known and many such charts have been constructed which are in daily use. The accompanying alignment chart is offered for the rapid evaluation of hydrogen ion concentration, alkalinity and carbon dioxide in water supplies.

The mathematical relationship used in the construction of this chart was proposed by Tillmans and stated as follows (1):

$$h = \frac{(\text{p.p.m. free } CO_2) \times 3}{(\text{p.p.m. bicarbonate alkalinity expressed as } CaCO_3) \times 0.61}$$

where h = concentration of H^+ expressed as $\frac{\text{mgm. per liter}}{10{,}000}$.

This equation can be evaluated into terms employing pH, alkalinity and CO_2, viz.:

$$\text{pH} = \log \frac{\text{Alkalinity (as } CaCO_3) \times 0.203 \times 10^7}{\text{Free } CO_2}$$

where alkalinity and CO_2 are expressed in parts per million.

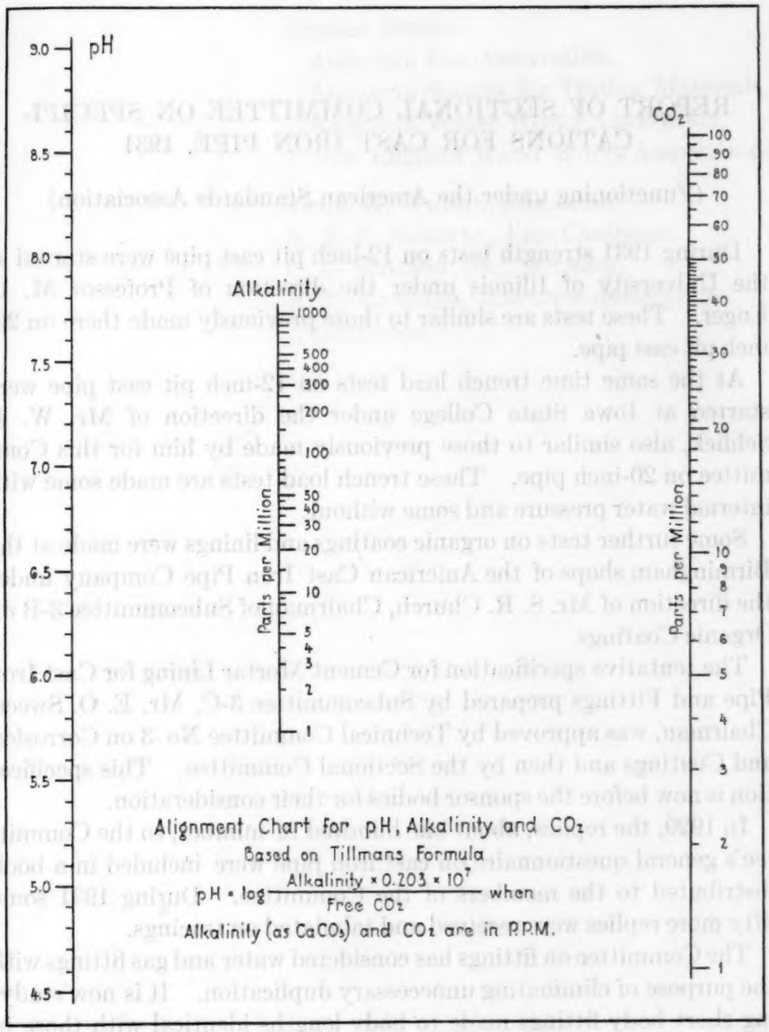
This nomogram should prove particularly useful in determining the characteristics of water from the standpoint of corrosion. It should also be valuable in the control of boiler waters, and water softening apparatus.

In using the chart a straight line is drawn through points representing any two determined values, such as pH and alkalinity. The intersection of this line with the CO_2 scale will give directly the CO_2 value in parts per million. Any other two determined values may be used in the same way to determine the third.

REFERENCE

(1) Wagner and Enslow: Journal, 9: 379, 1922.

[1] The Henry Souther Engineering Company, Hartford, Conn.



ALIGNMENT CHART FOR THE EVALUATION OF pH, ALKALINITY AND CO_2 IN WATER

REPORT OF SECTIONAL COMMITTEE ON SPECIFICATIONS FOR CAST IRON PIPE, 1931

(Functioning under the American Standards Association)

During 1931 strength tests on 12-inch pit cast pipe were started at the University of Illinois under the direction of Professor M. L. Enger. These tests are similar to those previously made there on 20-inch pit cast pipe.

At the same time trench load tests on 12-inch pit cast pipe were started at Iowa State College under the direction of Mr. W. J. Schlick, also similar to those previously made by him for this Committee on 20-inch pipe. These trench load tests are made some with internal water pressure and some without.

Some further tests on organic coatings and linings were made at the Birmingham shops of the American Cast Iron Pipe Company under the direction of Mr. S. R. Church, Chairman of Subcommittee 3-B on Organic Coatings.

The tentative specification for Cement Mortar Lining for Cast Iron Pipe and Fittings prepared by Subcommittee 3-C, Mr. E. O. Sweet, Chairman, was approved by Technical Committee No. 3 on Corrosion and Coatings and then by the Sectional Committee. This specification is now before the sponsor bodies for their consideration.

In 1929, the replies, about one hundred in number, to the Committee's general questionnaire on cast iron pipe were included in a book distributed to the members of the Committee. During 1931 some fifty more replies were received and tabulated on tracings.

The Committee on fittings has considered water and gas fittings with the purpose of eliminating unnecessary duplication. It is now studying short body fittings made to body lengths identical with those in the flanged standards of B-16, the Sectional Committee on Pipe Flanges and Flanged Fittings, to see if the losses of head in flow of water are sufficiently low, as determined by the tests made for the

Committee by Prof. E. W. Schoder of Cornell, to justify making these short fittings standard for water purposes.

Sponsor Bodies:
American Gas Association,
American Society for Testing Materials,
American Water Works Association,
New England Water Works Association.

THOS. H. WIGGIN, *Chairman*
N. F. S. RUSSELL, *Vice-Chairman*,
C. C. SIMPSON, JR., *Secretary*,
A. V RUGGLES, *Executive Assistant to Chairman.*

PROPOSED AMERICAN TENTATIVE STANDARD ON CEMENT MORTAR LINING FOR CAST IRON PIPE AND FITTINGS JULY 20, 1931

The Sectional Committee on Specifications for Cast Iron Pipe and Special Castings functions under the procedure of the American Standards Association and has as Sponsors the American Water Works Association, the New England Water Works Association, the American Gas Association and the American Society for Testing Materials.

This Sectional Committee has prepared a proposed American Tentative Standard on Cement Mortar Lining for Cast Iron Pipe and Fittings and in accordance with American Standards Association procedure has submitted this for preliminary approval to the four Sponsors. If and when these four bodies have approved the proposed specification, it will be submitted by them to the American Standards Association for approval as an American Tentative Standard.

So far, the draft specification has been approved by the American Gas Association. The American Water Works Association referred it to its Committee on Water Works Practice, which has recommended its approval.

By direction of the Board of Directors of the American Water Works Association the proposed standard is printed herewith in THE JOURNAL for the information of the membership and others interested and for the purpose of soliciting general comment and criticism. Any such comment and criticism should be sent to the office of the Secretary of the American Water Works Association, 29 West 39th Street, New York, N. Y.

This draft standard was prepared by Sub-Committee 3-C on Inorganic Coatings, of which committee the first chairman was James E. Gibson (Manager and Engineer of the Charleston, S. C., Water Department) who was chosen because of his pioneer work in the development and use of cement linings for cast iron pipe in Charleston. On Mr. Gibson's resignation he was succeeded as chairman by E. O. Sweet (Superintendent of the Birmingham, Ala., Water Works Company) who completed the draft in its present form. The draft was then passed to the superior committee, Technical Committee No.

3 on Corrosion and Protective Coatings, the chairman of which is Leonard P. Wood (Designing Engineer, New York Board of Water Supply). After approval by Technical Committee No. 3 the draft was passed to the Sectional Committee and received its approval.

The use of cement mortar linings for cast iron pipe has become common only within the last few years and the technique is changing and improving as time goes on. This will probably result in future changes in this specification from time to time. The specification, therefore, purposely avoided too definite limitations. This fact has caused some questions to be raised and it is thought that the following explanation will be useful.

The thicknesses of lining were increased from previous practice because of a conviction that former thicknesses did not offer sufficient assurance of adequately covering irregularities in the surface of the iron and in the straightness and dimensions of the pipe and did not afford sufficient body of cement mortar to promise long life where the water was corrosive to calcium carbonate.

The thickness was not made greater because the specified thickness was the greatest that the manufacturers believed could be applied without excessive trouble with shrinkage, causing loose spots or cracking.

The specification was not made more definite with respect to proportions of mixture, kind of cement and sand analysis, because no agreement could be reached in the present state of the art as to what were the optimum conditions and because the thicker linings demanded by this specification were beyond the commercial practice of the various manufacturers and were expected to require considerable experimentation and variation of manufacturing technique in order to produce the best linings of the new thicknesses. Experiments already made showed that extra care was needed for thicker linings.

The centrifugal process of application was not specified because it was felt that in the present state of the art the process should be left open to possible future developments.

In brief, the specification went as far as the state of a new art and the difficulties experienced by the manufacturers with thicker linings appeared to justify. It was frankly put out as a first step only toward a better specification with the expectation that the experience developed under it would furnish the ground work for further improvement.

The sub-committee on cement linings has in process at the Birmingham Water Works plant, where its chairman is Superintendent, some long time tests on different kinds of cement linings, designed to show the effects of independent variation of type of cement (four types), proportion of sand, and thickness of lining. These linings are in pieces of 6 inch pipe and in 6 inch elbows exposed to running water of a relatively soft, corrosive quality. From these tests it is hoped to learn something both as to proper composition and necessary thickness of lining to insure permanency.

Proposed American Tentative Standard on Cement Mortar Lining for Cast-Iron Pipe and Fittings, July 20, 1931

(*Note:* **This proposed standard is still subject to change, on the basis of comments received, before it is submitted to the American Standards Association for approval.)**

CEMENT

1. The cement used for making cement mortar shall be Portland cement, complying in all respects with the standard specifications of the American Society for Testing Materials, Serial designation C-9-21.

SAND

2. The sand for mortar shall consist of a clean, sharp, hard silicious sand, free from loam, clay, organic matter, or other foreign substance considered as deleterious for good mortar. The sand shall be well graded, and when tested by laboratory sieves, shall meet the following specifications:

Total passing 12 mesh sieve, 100 percent
Total passing 100 mesh sieve, not over 5 percent

CEMENT MORTAR

3. The cement mortar used for lining pipe shall be a mixture of the above specified sand and cement in such proportions as to obtain a good, hard, dense lining, reasonably well bonded to the pipe, and with a smooth interior surface. (A mixture which has been found to give very satisfactory results consists of three parts cement to one part sand, by volume.)

4. The cement mortar shall be thoroughly mixed, only sufficient water being added to form a workable mixture for placing in the pipe

5. Only sufficient cement mortar shall be mixed for the immediate requirements of lining.

6. The water for tempering the cement mortar shall be free from harmful amounts of oil, acid, alkali, organic or vegetable matter.

PREPARATION OF PIPE FOR LINING

7. Pipe to be lined with cement mortar shall not be coated inside with tar or other asphaltum products. Its interior surface shall be thoroughly cleaned of all core sand, mud, grease, foreign materials, or any sharp projections of iron which might project through the lining. Pipe shall be tested hydrostatically before being lined.

METHOD OF APPLYING THE CEMENT MORTAR LINING

8. Sufficient cement mortar shall be introduced to produce the required thickness of lining and spread evenly over the interior surface of the pipe, by any suitable means. A careful examination shall be made after this operation is completed to see that the inner surface of the pipe is completely covered with cement mortar.

9. The shoulder of the bell and the end of the spigot may be covered with cement mortar by applying with a brush.

10. Surplus cement mortar shall be removed from the interior of the bell so as not to interfere with proper keying of the joint.

11. The work of lining the pipe shall be done in a building where the product shall be protected from the direct rays of the sun, and from extreme weather conditions, such as rain, frost, etc. The product shall not be put on the yard until the cement has set sufficiently to avoid injury or damage thereto.

12. Patching of improperly lined pipe will not be permitted.

SMOOTHNESS OF LINING

13. The lining of straight pipe shall be smooth and substantially free from noticeable ridges, corrugations, projections or depressions. The lining of fittings shall be as smooth as practicable.

OUTSIDE SURFACE OF PIPE

14. Unless otherwise specified, no coating shall be applied to the outside surface of cement mortar lined pipe and fittings.

LINING FITTINGS

15. The interior surface of fittings shall be lined by applying cement mortar as specified in previous paragraphs, evenly and uniformly, and as nearly as practicable of the thicknesses specified for the corresponding sizes of pipe.

THICKNESS OF LINING

16. The minimum thickness of lining for the various size pipes shall be as follows:

Nominal size of pipe *inches*	Minimum thickness of cement-mortar lining *inch*
4	$\frac{1}{8}$
6	$\frac{1}{8}$
8	$\frac{1}{8}$
10	$\frac{1}{8}$
12	$\frac{1}{8}$
14	$\frac{3}{16}$
16	$\frac{3}{16}$
18	$\frac{3}{16}$
20	$\frac{3}{16}$
24	$\frac{3}{16}$

17. A plus tolerance of $\frac{1}{8}$ inch in thickness of lining shall be permitted on all size pipe from 4 to 24 inches. No minus tolerance to be allowed.

18. Linings of greater thickness will be furnished when specified.

19. The thickness of lining may be determined by means of spear measurement, using a hardened steel point not greater than $\frac{1}{16}$ inch in diameter. The inspector shall pierce the lining immediately after it is placed in the pipe, and before cement has set, at four diametrically opposite points of the pipe at bell and spigot ends, making two sets of measurements at each end. The first set shall not be greater than 4 inches from the respective ends of the pipe and the second set shall be made as far into the interior of the pipe as can readily be obtained by reaching into the pipe without injuring the lining.

20. All measurements shall be within the limits as specified.

21. At the ends of the pipe where the lining naturally tends to taper off to a thin edge, the full thickness of lining shall extend to within 1 inch of end of pipe.

22. For linings of the above specified thickness, or of greater thick-

ness, failure of the lining to completely adhere to the wall of the pipe shall not be cause for rejection, if the lining conforms to these specifications in all other respects (see Notes).

CURING CEMENT MORTAR LINING

23. Immediately after pipe is lined with cement mortar, it shall be protected in a suitable manner to prevent the too rapid withdrawal of moisture from the cement mortar, and if necessary, suitable means shall be provided to keep lining damp for a period of at least twenty-four hours after lining.

24. No pipe shall be shipped until the lining is thoroughly set.

NOTES

The above tentative specification provides for thicker cement linings than have generally been used in American practice. In view of the unavoidable irregularities in the inner surface of cast iron pipe, of the known solvent action of many waters on the lime content of Portland cement, and the limited experience (only about seven years) with thin Portland cement linings in cast iron pipe, thicker linings are believed to be desirable as a matter of insurance.

In the present state of the art such thicker linings are more prone, when dry, to a minute separation from the wall of the pipe; when wet, however, slightly separated cement linings swell into close contact with the pipe. The Committee believes that the thicker linings recommended will have longer life and will prevent tuberculation and maintain carrying capacity longer than thinner linings which may show somewhat less temporary separation from the pipe.

The Committee refrains from attempting, at this time, to specify the amount, or area, of the non-adherence of the lining which shall cause rejection. It is realized that the manufacturer will produce the best pipe he can and that it may require some little experimentation of each size and thickness of lining to secure the best adherence. The judgment and common sense of the inspector and of the manufacturer's forces are relied upon to secure the best practicable results during this period of development, rather than an arbitrary limit to the permissible area of non-adherence.

SECTIONAL COMMITTEE ON SPECIFICATIONS FOR CAST IRON PIPE

Organized April 21, 1926, Under the Procedure of

THE AMERICAN STANDARDS ASSOCIATION

THOS. H. WIGGIN, *Chairman*,
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SPONSOR SOCIETIES

American Gas Association
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American Water Works Association
New England Water Works Association

FRESH-WATER MUSSELS AND THE BACTERIAL CONTENT OF WATER

By M. P. Moon[1] and Eleanor Glenn[1]

The question of the bactericidal power of fresh-water mussels is one of practical importance in view of the ever-increasing amounts of sewage and other organic material in which bacteria multiply, which are being introduced into the streams inhabited by fresh-water mussels. Fresh-water mussels when confined in a tub or other small container will rapidly clarify considerable quantities of muddy or cloudy water. The fresh-water mussel pumps through its valves considerable quantities of water to meet the needs of the animal's respiratory and digestive activities, and special mucous secretions remove from the water which passes into the fresh-water mussel a considerable portion of the suspended matter contained in the water as it enters the shell. Some of this suspended matter finds its way into the alimentary canal of the fresh-water mussel, and it is believed by many fishermen and others that the fresh-water mussel purifies the water by freeing it from all suspended material and by digesting the bacteria themselves. We have been unable to find in the scientific literature any definite experiments proving this assumed bactericidal power. If such bactericidal power exists, it should be most practical in the destruction of the organisms of the intestinal tract. Accordingly a series of experiments has been carried on at the University of Missouri to check this question.

The fresh-water mussels used had been subject to the effect of running tap water in vats for a period of several weeks. Cultures were made from various parts of the fresh-water mussels and in no instance was B. coli found. Prescott and Winslow (1) found when "Oysters were removed from heavily polluted regions and carried to waters which were practically free from pollution, where they were

[1] Department of Preventive Medicine, School of Medicine and United States Bureau of Fisheries Research Laboratories, University of Missouri, Columbia, Missouri.

planted, that within four days the organisms of the colon type were practically eliminated."

The following fresh-water mussels were used:

Squaw foot	*Strophitus rugosus*
Pig toe	*Fusconia undata*
Hickory nut	*Obovaria olivaria*
Buck horn	*Tritogonia verrucosa*
Slough sand shells	*Lampsilis fallicosa*

The shells of the fresh-water mussels were scrubbed and washed, then covered with paraffin so that external contamination was elimi-

TABLE 1

Multiplication of bacteria in inoculated tap water; results expressed in bacterial colonies per cubic centimeter

EXPERIMENT NUMBER	ORGANISM USED	0 HOUR	24 HOURS	48 HOURS	72 HOURS	92 HOURS	120 HOURS
1	Staphylococcus	30,000	150,000	500,000		20,000	
5	Staphylococcus	32,500	1,000		126,500	62,500	
7	Staphylococcus	52,500	70,250	156,000	730,000	10,000	10,000
12	Staphylococcus	50,000	8,000	15,000	21,000	89,500	160,000
22	B. coli	580,000	875,000	967,000	715,000	172,500	4,500
26	B. coli	111,750	450,000	720,000	880,000	10,000	6,000
29	B. coli	135,000	360,000	500,000	300,000		
33	B. typhosus	130,000	550,000	200,000	220,000		
Average		136,000	390,000	390,000	336,000	60,000	90,000

nated as much as possible. The fresh-water mussels were placed in sterile battery jars containing 4 liters of tap water. One cubic centimeter of a 24-hour bouillon culture of the organisms used in the experiments was added. An incubation temperature of 19° to 22°C. was maintained by placing the jars in a bath of running tap water from which the light was excluded. This temperature was used because we considered it to be close to those of streams in which the fresh-water mussels are found.

Table 1 shows that, at the temperature maintained, the bacteria planted in clear tap water increase up to 24 to 48 to 72-hour periods, then suddenly decrease.

Table 2 shows that the fresh-water mussel alone adds bacteria to the tap water, there being a steady increase to the 96-hour period, which is followed by a rapid decrease.

This increase cannot be due to the bacteria present in the tap water, because the highest initial count of the tap water was not over 10 colonies per cubic centimeter, and after 4 days' incubation, the average count was less than 100 colonies per cubic centimeter. The conclusion was made that the tap water used is a negative factor from a quantitative consideration. No B. coli was found in cultures made from the water in which fresh-water mussels alone were placed.

In table 3, an even greater increase in the bacterial count is noted; the peak of the curve coming at the 72-hour period, with a sudden drop at the 96-hour period. It is shown that to the multiplication of the bacteria (as in table 1), is added the increase of the bacteria brought in by the fresh-water mussel itself (as in table 2), making the

TABLE 2

Increase of the bacterial content of tap water due to presence of fresh-water mussels; results expressed in bacterial colonies per cubic centimeter

EXPERIMENT NUMBER	0 HOUR	24 HOURS	48 HOURS	72 HOURS	96 HOURS	120 HOURS
3	7	3,000		21,500	67,250	
4	17	150		450	2,500	
8	6	4,192	6,300	12,700	5,000	500
10	35	5,088	12,450	7,800	600	50
13	11	4,500	150,000	200,000	1,200,000	512,500
15	43	300	1,300			
21	4	1,090	8,200	34,600	1,000	3,025
25	0	2	12,800	6,000	800	2,100
Average..	15	2,800	31,400	40,400	182,000	103,000

highest average count of table 3 twice as great as the highest average count in table 1, with the average initial count of each practically the same.

The decrease in the bacterial count at 96-hour period coincides with the decrease in the specimens which did not contain fresh-water mussels, as shown in table 1. This is probably due to the diminished viability of the organisms in the absence of food materials.

Two hundred cubic centimeters of bouillon were added to three containers. During the 24- and 48-hour interval, the fresh-water mussels died. Their death was probably influenced by the rapid multiplication of the bacteria.

These experiments seem to show that the fresh-water mussels do not prevent the multiplication of bacteria in the surrounding waters,

but actually add bacteria to the waters. Apparently the fresh-water mussels cannot be regarded as of any large importance in the destruction of stream bacteria. These experiments are being continued.

TABLE 3

Effect of fresh-water mussels on the bacterial content of inoculated tap water; results expressed in bacterial colonies per cubic centimeter

EXPERIMENT NUMBER	ORGANISM USED	0 HOUR	24 HOURS	48 HOURS	72 HOURS	96 HOURS	120 HOURS
2	Staphylococcus	20,000	120,000	40,000	70,000		
6	Staphylococcus	30,000	1,000		106,500	172,500	
9	Staphylococcus	84,250	35,750	397,000	725,000	150,000	20,000
11	Staphylococcus	56,300	77,750	630,000	1,440,000	50,000	20,000
14	Staphylococcus	70,750	85,000	120,000	600,000	930,000	922,500
17	Staphylococcus	149,250	250,000	140,000			
19	Staphylococcus	373,000	290,000	140,000			
23	B. coli	490,000	85,000	25,000	2,250	2,900	4,000
24	B. coli	385,000	275,000	102,000	15,750	5,500	11,750
27	B. coli	33,500	280,000	215,000	280,000	36,000	10,000
28	B. coli	94,250	300,000	1,132,500	1,000,000	20,000	6,000
30	B. coli	200,000	700,000	800,000	1,100,000		
31	B. coli	180,000	82,000	200,000	300,000		
32	B. coli	150,000	65,000	500,000	1,000,000		
34	B. typhosus	65,000	65,000	700,000	1,500,000		
35	B. typhosus	60,000	42,000	250,000	800,000		
36	B. typhosus	70,000	54,000	150,000	350,000		
Average		129,300	170,000	415,000	780,000	182,000	29,000

TABLE 4

Effect of bouillon on the bacterial content of inoculated tap water in the presence of fresh-water mussels

EXPERIMENT NUMBER	ORGANISM USED	0 HOUR	24 HOURS	48 HOURS
16	0	109	500,000	112,000,000
18	B. prodigiosus	160,000	2,300,000	16,000,000
20	B. coli	540,000	4,500,000	46,000,000

REFERENCES

(1) Prescott and Winslow: Elements of Water Bacteriology, 5th Edition.
(2) Park and Williams: Pathogenic Microörganisms, 8th Edition.

DISCUSSION

STEEL PIPE

The writer finds Mr. Birkinbine's paper[1] interesting and at the same time disappointing in that the author seems to have let his interest in and enthusiasm for steel pipe over-balance his better judgment. After reading the paper, the writer is in the frame of mind of the old water works plant engineer who had listened for some time to a salesman selling steam specialties for his boiler plant and who had come to the conclusion that, if he only were to purchase all of these accessories, with the increased economy guaranteed, he could run his boiler without any fuel whatsoever.

The author's enthusiasm for steel pipe has led him to make quite a few statements which are questionable, among which are included the following:

"In the majority of our large municipal water supplies steel mains are the sole channels for connecting the pump stations with the reservoir and/or this with the distribution system."

"Although there have been and will be cases where corrosive action of aggressive soils . . . . results in the penetration of the steel shell, failures have been so rare as to be considered as almost non-existent."

"Exterior, or soil, corrosion is seldom a serious matter being confined to relatively small sections of this country."

"Under average conditions there will be less detrimental results from interior corrosion in wrought than in cast ferrous mains"

"In my opinion too much stress has been placed on this subject of age of water mains

" . . . . Comparisons are made with cast iron pipe with no intention of reflecting on this well known material but to indicate the advantage of a more modern one"

Any one familiar with the operation of water works properties generally throughout the country will take each and all of the above statements at their true worth.

It should be noted, further, that a considerable discussion is given

[1] Journal, March, 1932, page 345.

in the paper to breakage, all of which could be covered by the simple statement that steel has a higher tensile strength and ductility than other pipe line materials. This, of course, is a well known fact and its importance is felt in high-value, congested districts of large cities where, after all, pipe lines of utilities properties of this nature should be placed in tunnels and should be accessible for repairs and replacement as required. This is the custom in some foreign cities.

While on this subject, it should be noted, as stated by Mr. Birkinbine, that a steel pipe seldom bursts, but on the other hand there are many instances of failure of steel pipes which have corroded to such an extent that it is no longer economical or feasible to repair them. Such pipes have been replaced, not because they have burst, but because they were no longer serviceable.

Mr. Birkinbine's discussion on carrying capacity with respect to the age of a pipe line is clever, but unfortunately is misleading. He has made the mistake of using a formula for cast iron which is satisfactory for new pipe, but which contains factors of capacity depending upon age which are no longer adaptable for present practice. The Williams-Hazen formula was developed on experiences where active waters prevailed and where the use of cement protective coatings on the inside of the pipe was practically unknown.

Neither were such terms, or features, as "active waters" or "pH value" known to the water works practice at the time when tests were made from which the Williams-Hazen age factors were developed. A fair comparison between steel and cast iron pipe would be, not as stated by Mr. Birkinbine, to compare the pipe on the basis of two different formulae, but rather to consider two separate lines, the one of steel and the other of cast iron, both placed, say in New England, and both carrying the same active water. After twenty-five years' service, doubtless the steel pipe would need replacing and the cast iron pipe would have lost some carrying capacity. That is the fair comparison of the two materials in the event that satisfactory inside protective coatings were not provided for either pipe. It is undisputed that, without a satisfactory protective coating, steel pipe in many conditions of service under ground, has comparatively short life. This fact will continue until such time as there is developed a satisfactory protective coating for both the inside and outside of the steel pipe. To date such a permanent protective coating has not been developed.

The paper contains the further statement that "leakage has been considered as an unavoidable loss." Such a statement is misleading and should properly be qualified. Later Mr. Birkinbine develops the fact that leakage of 1,250,000 gallons of water daily is worth $45,000 per year, or $1,000,000 capital investment. The writer has just received a report of a leakage survey made by The Pitometer Company for a city of 60,000 population. As the result of this survey, the water company eliminated a leakage of 1,250,000 gallons daily. Based upon Mr. Birkinbine's conclusions, the management of the water company should pay The Pitometer Company $1,000,000 for its investigations instead of the nominal fee actually paid. The discussion on leakage from steel, as compared with cast iron, pipe would be more convincing if it had presented figures taken from actual tests to show that leakage from steel pipe lines was less than that experienced from cast iron pipe lines. Any assumption of leakage without such test data may be grossly misleading.

Mr. Birkinbine concludes with a lengthy discussion of comparative costs of steel and cast iron pipe varying in diameter from 4- to 24-inch. If we believe what is stated in this discussion, we are forced to the conclusion that water work operators all over the country have been erring grievously in using cast iron pipe for distribution systems made up of pipe of these sizes. It is impossible to think that the water works profession has for years been making the serious mistake of substituting cast iron for steel pipe. The former has proven more satisfactory throughout the long period during which it has been tested by actual use.

The writer is disappointed in Mr. Birkinbine's paper, in that he does not present more advanced information on the steel pipe industry, particularly with respect to recent development of protective coatings and with respect to best methods of manufacture and field erection for steel pipe lines. The writer cannot escape the impression that Mr. Birkinbine has been too much concerned with the qualities of other pipe line material to present an instructive paper on the real merits of steel pipe. The writer will look forward to the time when Mr. Birkinbine will prepare for the water works profession a paper without obvious prejudice against any other pipe line material and without presenting data in such a way that they savor of propaganda.

SOCIETY AFFAIRS

THE ROCKY MOUNTAIN SECTION

The Rocky Mountain Section of the American Water Works Association enjoyed a registered attendance of 101 at its fifth annual meeting held in Denver, October 21–23, 1931. With representation from points as distant as Artesia, New Mexico, Cody, Wyoming, and Sidney, Nebraska, the drawing power of this meeting was apparent.

Featured on the program for the first day was a most interesting, valuable, and timely talk by Mr. R. L. Dobbin, President of the American Water Works Association, who journeyed from his home in Peterborough, Ontario, Canada, to attend this meeting. The question box, a novel presentation of round table discussion, and various technical papers together with a business session, made up the balance of the first day's program. At the business session the election of officers and trustees resulted as follows: Chairman, G. C. Culberson, Raton, New Mexico; Vice Chairman, office discontinued; Trustees (previously called Directors), terms ending 1934: D. V. Bell, Rock Springs, Wyoming (reëlected), Paul S. Fox, Santa Fe, New Mexico (reëlected); term ending 1932: L. C. Osborn, Loveland, Colorado (exofficio as retiring Section Chairman); Director of American Water Works Association from Rocky Mountain Section, Burton Lowther, Denver, Colorado.

The second and third days of the meeting were featured by a water works college sponsored by the Extension Division of the University of Colorado. During the forenoon sessions technical papers more on the order of lectures were presented by persons particularly competent to speak on their respective subjects. The first morning session was devoted to the general subject of the quantity of water and the second to the general subject of the quality of water. Inspection trips were included in the program for the two afternoon sessions. Engraved certificates were presented by the University of Colorado to all persons attending the two days of the water works college and evidencing interest in the sessions.

A smoker on the first night of the meeting, during which many

interesting industrial motion pictures were shown, and a banquet followed by lively and interesting entertainment held on the last night of the meeting, together with entertainment for the ladies including a bridge tea, an automobile tour over the city, and a theatre party, rounded out the social side of the meeting.

Exhibits of water works construction materials, made possible by special authorization of the Manufacturers Association, added materially to the meeting.

Selection of the date and place for the next annual meeting of this Section was left to the executive committee with the general admonition that it should be in the fall of 1932 and in Denver. It is interesting and perhaps odd that the Section has shown a definite and practically unanimous desire to hold their meetings in the city of Denver.

The proceedings of the meeting including the lectures given during the water works college, will be printed and distributed throughout the Section territory through the courtesy of four Denver water works firms.

DANA E. KEPNER
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Geophysical Study Predicts Rock Conditions at Tunnel Site. E. E. Carpenter and E. G. Leonardon. Eng. News-Rec., 105: 364–5, September 4, 1930. Brief explanation of theory of rock resistivity upon which is based technique of geophysical exploration, together with outline of application of method in connection with 13,200-foot Bridge River tunnel recently completed by British Columbia Electric Railway Company. Decided change appeared in material encountered at point 1020 feet from entrance. Rock became much softer and more fractured and coincidently small water occurrences were encountered. At 1220 feet, strong flow of water under heavy pressure invaded tunnel, causing crushing of heavy timbering and complete collapse over length of more than 200 feet. With aid of electrical prospecting from rock surface, tunneling was successfully resumed along another line. Diagram is included showing accuracy of predictions of rock conditions based upon geophysical exploration. Similar measurements may be made from drill holes, information thus obtained supplementing precise, but local, information obtained by examination of material removed by drill.—*R. E. Thompson.*

Eleven-Mile Canyon Reservoir Permits Denver to Use Full Storage of Lake Cheesman. D. D. Gross. Eng. News-Rec., 105: 425–6, September 11, 1930. Description of conditions leading to construction of Eleven-mile Canyon dam and reservoir on South Platte River. Estimated cost is $1,150,000. Chief function of Lake Cheesman reservoir, several miles below new reservoir, is to hold 50,000 acre-feet of water in reserve for use in long periods of drought. As total capacity is only 79,000 acre-feet, only the upper 29,000 acre-feet can be safely used. Average use from this source to date is 20,000 acre-feet per year. New reservoir, by storing necessary reserve higher up on river, will enable whole capacity of Lake Cheesman to be utilized each year if necessary. Flow of river is variable, being in some years less than 79,000 acre-feet, in other years, much more.—*R. E. Thompson.*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

A Comparison of Lactose Broth and Lactose Bile as Enrichment Media for the Detection of Pollution in Farm Well Waters. A. G. Lochhead and D. G. Hewer. Can. Pub. Health J., 22: 10–15, 1931. Results of comparative tests on 482 samples are tabulated. Lactose broth was prepared in accordance with "Standard Methods;" lactose bile medium contained 10 grams peptone, 10 grams lactose, and 50 grams ox bile per litre, Difco dehydrated products being employed throughout. Two 10-cc. portions, two 1-cc. portions, and one 0.1-cc. portion of each sample were planted in each medium and incubated at 37°C. Positive tests were confirmed by transfers to Levine's eosin-methylene-blue agar, two isolated colonies being transferred to agar slants, preference being given to those considered to be of fecal type. Cultures thus obtained were examined by usual procedures. Gram-negative, non-liquefying, lactose-fermenting rods were considered members of the coli-aërogenes group, while those which, in addition, gave positive methyl-red and negative Voges-Proskauer tests and showed black, usually with more or less pronounced metallic sheen, on eosin-methylene-blue agar were considered *B. coli*. Results after 24- and 48-hour incubation of presumptive tubes are shown separately, distinction being also made between the formation of gas occupying more and less than 10 percent of the inverted vial. Of 2410 tubes of each medium inoculated, 1263 and 1199 tubes, of lactose broth and lactose bile respectively, showed gas formation; coli-aërogenes group organisms being isolated from 960 of former and 962 of latter, and fecal type *B. coli* from 649 of former and 782 of latter. It is of interest to note that coli-aërogenes organisms were isolated from 61 of 229 tubes of lactose broth showing less than 10 percent of gas in 48 hrs., and from 29 of 172 similar lactose bile tubes, isolations of fecal *B. coli* from these tubes being 26 and 22 respectively. These results indicate that there is no advantage in employing lactose bile, if presence of coli-aërogenes group organisms is regarded as criterion of pollution; but that lactose bile is to be preferred, if fecal type *B. coli* are regarded as the index of pollution.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Water Works and Sewerage Activities in Ontario. A. E. Berry. Cont. Rec. and Eng. Rev., 44: 1633–7, 1930. Review of works recently completed, in progress, and projected in Ontario. At close of 1930, 275 municipal water works systems, capable of supplying in excess of 2,000,000 people, were in operation. Practically all communities of 1000, or more, population are now served by public systems. Surface sources provide water for 60 percent of systems, deep wells for 26 percent, and springs for 14 percent. Over 80 percent of water supplied is chlorinated and 35 percent is filtered.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Encasing Wood Stave Pipe at Niagara Falls, Ont., with Reinforced Concrete. Cont. Rec., 44: 1435–6, November 19, 1930. Brief description of encasement in concrete of 4500 feet of 13½-foot wood-stave pipe serving power house of Hydro-Electric Power Commission of Ontario. When constructed 12 years ago, concrete envelope was placed over those sections at either end that were to be backfilled with heavy overburden of earth and rock. Some 4500 feet of pipe was left exposed in open trench. In order to permit landscape improve-

ment and prevent further deterioration of staves and steel bands, it was decided to cover exposed portion. Sufficient reinforcing was incorporated to withstand entire water pressure and permit removal of staves when desired. Thickness of staves is 4 inches and minimum thickness of concrete envelope, 15 inches. Transit-mixed concrete was employed.—*R. E. Thompson.*

Making a Snow Survey to Measure Probable Runoff. BYRON E. WHITE. Eng. News-Rec., **106**: 81, January 8, 1931. Brief description of procedure employed in making snow survey with improvised equipment consisting of rain-gage can, 8 inches in diameter and 20 inches deep, 24-pound spring scale, and rule. Can was plunged vertically into snow, a trench shoveled or stamped with feet to enable can to be laid over on side and contained snow weighed. Where depth of snow exceeded 20 inches, can was pressed down twice in same place. From data so obtained, water equivalent was readily calculated.—*R. E. Thompson.*

Diagram Gives Flow of Water in Pipes. H. L. POWELL, Jr. Eng. News-Rec., **106**: 78, 1931. Directions are given for preparation of a simple nomograph, based on the Chezy formula, for solving problems relating to flow of water in pipes.—*R. E. Thompson (Courtesy Chem. Abst.).*

Flow of Water Around Bends. E. M. SHEPHERD. Eng. News-Rec., **106**: 82, January 8, 1931. Outline of method employed in making observations on direction of flow in river model, consisting of suspending crystals of potassium permanganate on fine copper wire at suitable points and observing resulting colored filaments. Corkscrew action at bends, toward outer bank near surface with return current along bottom, was very well illustrated.—*R. E. Thompson.*

Floodway Friction Factors for Fairly Well-Defined Channels. F. C. CAREY. Eng. News-Rec., **105**: 612, October 16, 1930. Brief data on methods employed and observations made by United States Engineers of New Orleans River District on flows across a narrow neck called Cowpen Neck during Mississippi rise of March and April, 1929. The land is covered with good growth of cottonwood, willow, and sycamore trees, varying from 8 inches to 2 feet in diameter, with but little underbrush except low weed growth. Observations were made along a number of fairly well-defined channels traversing the area where timber is larger and undergrowth is largely absent. Mean depths varied between 2.3 and 12.5 feet, velocities between 0.865 and 3.4 feet per second, and Kutter's n between 0.036 and 0.186, average of all observations being 0.086. Values are only for these rudimentary channels and are not applicable to entire areas. In future work, courses will be laid out away from channels of higher hydraulic efficiency.—*R. E. Thompson.*

Shop-Made Plug for Small Pipes. C. W. BILADEAU. Eng. News-Rec., **105**: 424, September 11, 1930. Brief illustrated description of device used in Pittsfield, Mass., for stopping flow from old services not equipped with curb shut-off valves. Device permits installation of valve without shutting down street main, when repairs are necessary.—*R. E. Thompson.*

Iodine Prophylaxis and Endemic Goiter. A. T. CAMERON. Can. Pub. Health J., 21: 495–506, 541–8, 1930. Extensive discussion and review of literature on distribution of I in nature and its correlation with thyroid diseases, particularly simple endemic goiter. Close relationship between deficiency of I in diet and simple goiter is indicated. Other possible causes of endemic goiter are discussed. There is strong evidence that in certain regions water-borne infection is a factor, but this probably acts through an effect on I metabolism. It is concluded that iodized salt is best medium for I prophylaxis. The I content of Canadian iodized salt (1 part KI or NaI to 10,000) seems unnecessarily high, and is perhaps 10–20 times greater than required. The evidence that iodized salt is potentially dangerous for adult (non-toxic) goitrous individuals is frequently open to criticism, and gravely exaggerated. Further study of this aspect is desirable. Bibliography of 60 references is appended.—*R. E. Thompson (Courtesy Chem. Abst.).*

Unique Cutoff Construction and Arched Foundation Features of Rodriguez Dam. Eng. News-Rec., 105: 600–4, October 16, 1930. Illustrated description of construction of Rodriguez dam on Tijuana River in Mexico. Serious fault in streambed, revealed only by actual excavation, necessitated unusual foundation treatment, which consisted of building cutoff wall from streambed downward as excavation was advanced through shafts and providing an arch to support 4 buttresses. The structure, which will be highest Ambursen-type dam ever constructed, will be 187 feet high above streambed elevation and about 240 feet high above lowest foundation rock, crest length being almost 2200 feet. It will store 110,000 acre-feet of water for irrigation.—*R. E. Thompson.*

Cast Iron Pipe Failures. M. G. SPANGLER. Eng. News-Rec., 105: 378, September 4, 1930. Brief discussion of value of cradling, in which it is pointed out that if concrete cradle acts to reduce normal settlement of conduit, load on pipes will be increased and advantage of greater support may be partly or wholly dissipated. Principle of laying pipe on earth cushion is sound.—*R. E. Thompson.*

Observations on Suspended Matter in the San Juan River. C. S. HOWARD and S. K. LOVE. Eng. News-Rec., 105: 620–1, 1930. Data obtained in studies carried out in 1928 and 1929. At certain times, the San Juan is one of muddiest rivers in United States. In general, river carries larger percentages of suspended matter with greater volumes of discharge; but quantity carried at any given discharge may cover a wide range. During period July 1 to September 21, 1929, mean content of suspended matter was 7.30 percent and mean daily load more than 1,500,000 tons, mean flow being about 8,000 second-feet. On one occasion suspended matter content was as high as 40.8 percent.—*R. E. Thompson (Courtesy Chem. Abst.).*

Constructing a 14-Mile Tunnel for Boston's New Water Supply. Eng. News-Rec., 105: 420–4, September 11, 1930. Detailed description of construction of 14-mile Wachusett-Coldbrook tunnel for Boston water supply system, now

approaching completion. This will complete first unit of Metropolitan District Water Supply Commission's program to provide city with additional 191 m.g.d. supply. Tunnel, for most part, consists of horseshoe-shaped section equivalent to 12-foot 9-inch circle, inside concrete lining. Control works and diversion dam are being installed at inlet shaft on Ware River. General plan of control works is to divert water through several siphon spillways of various capacities, which will ensure complete diversion above prescribed limit and prevent any diversion below this limit. Spillways will discharge into large well directly over shaft, from which fall into shaft will be controlled by 4 large butterfly valves, automatically maintaining water seal for exclusion of air and ensuring submergence of 800-m.g.d. Venturi meter set vertically over one of valves. During extreme floods in excess of meter capacity, quantity may be estimated from measurements at other points.—*R. E. Thompson.*

Zeolite Water Softening Plant Installed at Springdale, Pa. J. F. Pierce. Eng. News-Rec., **105**: 800–2, 1930. Recently completed softening plant at Springdale is described and illustrated. The well water, which has temporary hardness of from 190 to 368 p.p.m. and permanent hardness of from 0 to 127 p.p.m., is pumped to elevated tank from which it flows under uniform head to 2 upward-flow base-exchange softening units, with combined capacity of 610,000 gals. per day. Regeneration and washing are also by upward flow, rate during softening being 6, and during washing and regeneration, from 4 to 8 gallons per square foot per minute. Sufficient hard water is by-passed to adjust final hardness to 4 grains per gallon. Six percent brine is employed for regeneration. Length of runs and wash period are controlled by soap tests. Water is chlorinated prior to distribution. Bonds were issued directly against the municipally owned plant, earnings of plant being pledged for interest and sinking fund charges; increase in general bonded indebtedness of community thus being avoided.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Corpus Christi Dam Fails with Loss of North Abutment Wall. Eng. News-Rec., **105**: 861, November 27, 1930. New water supply dam of Corpus Christi, Texas, on Nueces River, about 35 miles northwest of town, failed on November 23 with loss of north concrete abutment of spillway section and about one-half of earth embankment at that end of dam. Damage, estimated at $100,000, is confined mostly to dam. According to the consulting engineers, undermining of north counterforted abutment wall was apparent cause of failure. It is believed that coastal earthquake, reported some 3 weeks previously might have sprung joints in interlocking steel sheet-piling cutoff wall under dam, permitting excessive seepage under base of abutment. Water supply is in no danger of exhaustion. Dam will be repaired at once.—*R. E. Thompson.*

Sanitary Engineering and Public Health in Manila, P. I. Harold E. Babbitt. Eng. News-Rec., **105**: 808–10, 1930. Water supply (cf. C. A., *22*: 3245), sewage disposal, and mosquito control are described. Sewer system serves only about one-third of city, remainder being served either by septic tanks, which discharge into surface drains, or by pail, or by dry system. Sewage is discharged into the ocean about ½ mile from shore. Mortality rates

for typhoid and dysentery in 1928 were 57.31 and 40.7 per 100,000, respectively. —*R. E. Thompson* (*Courtesy Chem. Abst.*).

Joint in Cast Iron Siphon Sealed from Within. FRANK P. MORSE. Eng. News-Rec., 105: 858, November 27, 1930. Joint leakage in inverted pipe siphon carrying part of Salem's water supply has been eliminated by use of standard sleeves placed within pipe. The 30-inch pipe in question passes beneath tidal stream approximately 40 feet wide, with bottom of siphon 25 feet below mean high water. The two joints which gave trouble are located in vertical limbs below water level. Calking from outside was unsuccessful. Pipe was disconnected at each side of siphon and water pumped out after leaking joints had been temporarily calked by diver. A 24-inch standard sleeve, turned down in lathe to make fairly close fit, was lowered into each limb and centered opposite joint with aid of 4 set-screws which projected from sleeve into joint crevice. Space between bottom of sleeve and pipe was then calked and hot lead poured into annular space from small pail fastened on end of pole, upper edge of sleeve being chamfered to minimize spilling. Neither joint has shown any sign of leakage in 3 years.—*R. E. Thompson.*

Methods of Financing Sewerage Systems. HARRISON P. EDDY. Eng. News-Rec., 105: 727–8, November 6, 1930. Outline of basic principles involved in financing, including bonds, taxation, special assessments, and servi e charges. While relating particularly to financing of sewerage systems, principles are general and apply to public works of any kind.—*R. E. Thompson.*

Overheating of Aggregates Found Detrimental to Concrete. WILLIAM H. BACHELDER. Eng. News-Rec., 105: 973, 1930. Strength and flow tests on concrete prepared with aggregates and mixing water heated to give batch temperatures of 70°, 100°, and 130°F. when discharged from mixer are shown graphically. Measuring workability by flow, 5.7 gallons of water per sack of cement were required for 70° concrete, 6.07 gallons for 100° concrete, and 6.85 gallons for 130° concrete to obtain the same workability when using a 1:2.07:3.12 mix by weight. Strength tests indicated that concrete placed at 130° loses approximately 20 percent of its strength and that less than half the loss in strength is due to the higher water-cement ratio. No attempt was made to prevent loss of heat after concrete was placed. Tests for water-content indicated that about one-sixth of additional water used in 100° concrete and about one-fourth of that used in 130° concrete were lost before concrete was tamped. As would be expected, time of setting was reduced by heating the mix.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Supplying Water to a Large Memorial Fountain. CHARLES B. BURDICK. Eng. News-Rec., 105: 724–6, November 6, 1930. Details are given of hydraulic problems involved in design of water system for Buckingham memorial fountain in Chicago. Fountain is about 280 feet in diameter and has 133 jets varying in height to throw to maximum of 100 feet. Night illumination is provided in 5 colors. There are two chief forms of display, the minor requir-

ing 5,000 gallons of water per minute and the major, 13,000 gallons per minute. —*R. E. Thompson.*

The Various Types of Water Meters. H. B. MILLARD. Cont. Rec. and Eng. Rev., **44**: 1524–6, December 10, 1930, and **45**, 8–9, January 7, 1931. Description of various types of water measuring devices, their operation and applications, including positive and inferential meters, weirs, weir recorders, current meters, Venturi meters, orifice meters, and pitometer.—*R. E. Thompson.*

Well Development by Siphons at South Bend. Eng. News-Rec., **105**: 414–5, September 11, 1930. Presence of thick layer of water-bearing sand directly beneath South Bend, Indiana, with extensive gathering ground on adjacent higher ground, makes available abundant supply of ground water. Pollution by surface drainage, inoluding highly polluted St. Joseph River, is prevented from reaching underflow by heavy clay blanket overlying sand. With static head of water in wells not more than 10 feet below ground level, use of siphon principle greatly simplifies development and makes unnecessary multiplicity of pumping units for the 100 or more wells in use. Suction leg of siphon is formed by well casing and discharge leg consists of pipe carried to bottom of concrete well from which high-lift pumps take their suction. The two siphon legs are connected by line of cast iron pipe with flanged joints buried below frost line, to which is connected vacuum pump for removing air and maintaining negative pressure in head of siphon. At each of the 3 development stations within city a number of wells are connected to one collector pipe discharging into single concrete suction chamber. At Oliver Park station, diagram of which is shown, 27 twelve-inch wells are arranged in 2 rows about 75 feet apart. Between rows is laid collecting header pipe varying in diameter from 8 to 36 inches, to which each well is connected by 8-inch lead. Header pipe enters wall of 18-foot diameter concrete well and by means of downturned tee is carried to within few feet of bottom. Upstanding leg of tee is covered with blank flange into which is tapped a 2-inch suction connection for vacuum pump. Latter is operated to produce vacuum of 25 inches of mercury at this point, a 34-foot high loop of pipe being provided to prevent drawing of water. Average daily consumption is 10 million gallons. City is 100 percent metered. —*R. E. Thompson.*

Control of Filtered Water. P. SORENSEN. Ingenioren (Copenhagen) **38**: 22, 263–4, 1929. From Chem. Abst., **24**: 2218, May 10, 1930. Description of apparatus developed by Copenhagen Water Supply Department for controlling iron and manganese content of drinking water supply.—*R. E. Thompson.*

An Early Chapter in the History of Water Filtration. Eng. News-Rec., **105**: 609–10, October 16, 1931. It is generally accepted that earliest slow sand filters were those of Chelsea Waterworks Company supplying portion of what is now Greater London. Occasionally reference is made to earlier use of filtration. In this connection data supplied by CHARLES F. MARSH, deputy chief engineer, Metropolitan Water Board, London, England, are given. An experimental filter was installed by JAMES SIMPSON at Chelsea water works, near Grosvenor

Road, Pimlico, in 1827, after he had seen several large filters at work in Manchester and Glasgow, and in December of that year he put forward working plans and specifications for proposed filter bed. Latter was put in operation in January, 1829, and proved satisfactory. MARSH believes that filtration works at Manchester and Glasgow were really infiltration galleries in gravel and sand adjacent to rivers and were not artificial slow sand filters. In 1852, intake was moved to Surbiton and on completion of new filtration plant in connection therewith in 1856, original filter was abandoned. It appears that SIMPSON visited many places in addition to Manchester and Glasgow, traveling some 2000 miles and inspecting "filter beds" which had given satisfaction for working periods of "from four months to sixteen years." The Chelsea bed occupied about 1 acre, the sides being of brickwork. Water was allowed to settle in 2 adjoining reservoirs covering $1\frac{1}{2}$ acres before passing on to sand. About $2\frac{3}{4}$ million gallons (U. S.) was filtered daily. Cost of construction, including reservoirs, was nearly £12,000 and annual operating cost was estimated at about £1,000. Bed, prior to filling with water, had appearance of several channels parallel to each other, formed by banks made of 3 two-foot layers of fine gravel, finer gravel and coarse sand, and fine sand, respectively, carefully laid over open-joint brick tunnels. It was found that suspended matter rarely penetrated further than about 3 inches below surface and that removal of sediment by scraping to depth of about $\frac{1}{2}$ inch usually restored efficiency of filter. Ice to depth of several inches on water in beds did not interfere with filtration process. Most of above information was obtained from "Hydraulia; An historical and descriptive account of the waterworks of London and the contrivances for supplying other great cities in different ages and countries," written by WILLIAM MATTHEWS and published in 1835.—*R. E. Thompson.*

Los Angeles Water Demand Hastens Aqueduct Extensions. Eng. News-Rec., 105: 429–30, September 11, 1930. During summer months of 1930, Los Angeles consumed twice the volume of water delivered through Owens Valley aqueduct. On May 20, bond issue of $38,800,000 for extension and improvement of existing supply system was approved by electors and city is now engaged in extracting all water available from sources tributary to Owens Valley aqueduct. These developments in nowise affect plan for Colorado River supply. Largest item in increasing present supply is flow to be diverted into Owens Valley basin from Mono basin, utilizing water rights to be purchased from Southern Sierras Power Company. Three different routes for bringing in this additional supply are now being investigated. As originally planned, Owens Valley aqueduct was designed for maximum flow of 400 second-feet, based on value 0.014 for n in KUTTER's formula. It is now believed that this value can be reduced materially, possibly to as low as 0.0125, by lining some of tunnels and canals. This work is not required on entire aqueduct as portions were built with capacity of 500 second-feet. Improvement of conduit surface should increase capacity to 440 and possibly to as much as 470 or 480 second-feet. In recent bond issue, $600,000 was included for this work. It is planned to carry out the work during winter season of 3 consecutive years. Each winter 5 shutdowns of about 10 days each will be scheduled at intervals that

will impose minimum interference. Experience has demonstrated that not more than about 300 second-feet can be relied on from present sources. Mono supply is expected to yield minimum of 130–140 second-feet. During past summer as much as 265 second-feet was being pumped at one time from wells in Owens Valley. Studies are being made with view to extending storage capacity in Los Angeles, developing underground storage basins, and utilization of all desirable well supplies.—*R. E. Thompson.*

Sewage Reclamation in Southern California. Eng. News-Rec., **106**: 367, February 26, 1931. Owing to rapid increase in population and growing inadequacy of local water resources, communities of southern California are engaged in intensive study of sewage reclamation as aid to water conservation. Long-time experiments have been started in Los Angeles and other places to determine practicability of utilizing sewage plant effluents for replenishment of ground water basins—*R. E. Thompson.*

Oil Burner Used in Recarbonation of Lime-Softened Water. James A. Worsham. Eng. News-Rec., **105**: 649, 1930. New water supply of Bloomington, Ill., derived from Money Creek, although softer than water formerly supplied from deep wells, contains about 250 p.p.m. of hardness. It is softened by excess lime method and recarbonated with CO_2 produced in commercial oil burner installed in low-pressure boiler which supplies heat and hot water for the offices. Flue gases are diluted with air from 15 percent to 4 percent CO_2, scrubbed, compressed, and dried; scrubber consisting of bed of coke sprayed with water. Oil consumption is 3 quarts per hour. Daily water consumption is about 2 million gallons.—*R. E. Thompson (Courtesy Chem. Abst.).*

Gaging Car over Columbia River Runs on 1,237-Foot Cable Span. Eng. News-Rec., **105**: 858, November 27, 1930. Brief description of unusual stream-gaging cable recently completed by Water Resources Branch, United States Geological Survey, across Columbia River at The Dalles, Oregon. With clear span of 1,237 feet and clearance of 75 feet above low water, this is one of largest installations of kind ever erected. Discharge measurements are made from 2-man steel gaging car which will be moved by hand into positions 30 feet apart for observations of depth and velocity. Improved Price meter with 100-pound weight is suspended by airplane strand wire, return circuit for electrical earphones being through water. Meter is operated by use of Au-Lee hand reel with dial for recording position of meter and depth.—*R. E. Thompson.*

Oil Pollution Committee Named by Engineering Council. Eng. News-Rec., **106**: 943, December 11, 1930. Joint committee on oil pollution, composed of members of national engineering societies, has been appointed by American Engineering Council, Robert Spurr Weston being chosen as chairman and Abel Wolman as secretary.—*R. E. Thompson.*

Progress in Water Supply and Purification during the Past Year. Norman J. Howard. Cont. Rec. and Eng. Rev., **44**: 1625–32, 1930. Extensive

review of progress during 1930 in waterworks field. Noteworthy advances were more widespread employment of softening and extending use of the ammonia-chlorine process for taste prevention. Many large water works construction programs are in progress in Canada.—*R. E. Thompson (Courtesy Chem. Abst.).*

San Francisco Signs Contract for Emergency Water Supply. Eng. News-Rec., **105**: 863, November 27, 1930. To avert possibility of water shortage should seasonal rains be insufficient, city of San Francisco has signed contract with East Bay Municipal Utilities District under which latter agrees to supply San Francisco with water in case of emergency. Agreement provides for standby charge of $292,000, to be paid prior to June 1, 1931, regardless of volume taken. San Francisco is to pay all charges, as well as cost of line from Newark to San Lorenzo, cost of connections and of pumping across bay through Pulgas tunnel into Spring Valley Lakes. City is not required to take water, but if water is taken volume must not be less than 5 or more than 20 million gallons per day. Charge for water will be 4 cents per 100 cubic feet. Period covered by agreement is 3 years, during which time it is expected that Hetch Hetchy aqueduct and tunnel system will be completed. Total expenditure for this emergency supply will be about $1,096,000.—*R. E. Thompson.*

Hetch Hetchy Tunnel Construction. Eng. News-Rec., **106**: 96–100, January 15, 1931. Advancing from 14 headings, tunnel driving is about 40 percent completed on 28½-mile bore through Coast Range, which is last mountain barrier to be pierced before water can be delivered in San Francisco. When nearer completion, the 47 miles of pipe line will be laid across San Joaquin Valley to connect east portal with western end of Foothill Division tunnels; this will finish aqueduct line. Tunnel will have inside diameter of 10½ feet and capacity of 300 million gallons per day, which will be adequate for many years. For ultimate development of 450 million gallons per day, a similar parallel bore 175 feet south is proposed. Formation penetrated is sedimentary and tunnel is timbered almost continuously. Gunite sub-lining, 18–24 inches thick, is being used in some rather extensive sections of heavy ground where uneconomically heavy timbering would have been necessary. All work is being carried out by construction forces of city. Methods employed are described in some detail.—*R. E. Thompson.*

New York Subway Construction. Eng. News-Rec., **105**: 200–5, August 7, 1930, 371–5, September 4, 1930, 455–8, September 18, 1930, 796–800, November 20, 1930, **106**: 136–40, January 22, 1931. Illustrated description of major problems in construction of New York City's third subway system. Construction and equipment cost of the 55 miles of line will be $650,000,000. Tunnel structure in rock consists of semicircular concrete arches. Soft ground and subaqueous tunnels are lined with cast iron segments with interlining of concrete to give smooth surface, only exceptions being short sections lined with precast concrete blocks. Fourth article of series is devoted to latter, which is innovation in subway construction.—*R. E. Thompson.*

Full-Circle Section of 17-Foot Tunnel Lined in Single Pour. Eng. News-Rec., 105: 610–2, October 16, 1930. Details given of arrangement by which concrete is being placed pneumatically in full-circle sections, 40 feet long, in Cushman No. 2 tunnel, near Tacoma, Washington. Copper water stops are being placed in all circumferential joints. Tunnel is 13,000 feet long.—*R. E. Thompson.*

Methods Used for Construction of Bridge River Tunnel. Cont. Rec. and Eng. Rev., 44: 1425–7, November 12, 1930. Description of construction of 2½-mile tunnel through Mission Mountains, recently completed as part of Bridge River power project of British Columbia Electric Railway Co. Section of tunnel, which somewhat resembles horseshoe, is equivalent to 14½-foot circle.—*R. E. Thompson.*

Athens Water Supply Tunnel Holed Through. Eng. News-Rec., 106: 295, February 12, 1931. Boyati tunnel, 8½ miles long, through Parnes Mountains, holed through on February 9, is said to be longest hydraulic tunnel in Europe and is one link of $11,000,000 water supply system for Athens. Engineers are utilizing section of aqueduct built by Roman Emperor Hadrian in 130 A.D. Ulen and Company of New York, who have contract for tunnel, have also joint contract with Bank of Athens to manage the water system for 25 years.—*R. E. Thompson.*

Novel Shield and Hexagonal Concrete Liner Blocks Features of Tunnel Job. Eng. News-Rec., 105: 771–3, November 13, 1930. Illustrated description of construction of electric conduit tunnel, 4 feet in diameter and 100 feet long, just completed for Philadelphia Electric Company under busy 4-track main line of Pennsylvania Railroad. Although bore has but 5 feet of cover, rail traffic overhead was not disturbed or slowed down during construction. Progress of 20 feet per day (10-hour shift) was made through hard, sandy clay material containing considerable number of small boulders. Lining consists of hexagonal concrete blocks 5 inches in thickness. One complete ring of lining contains 18 blocks, but because of hexagonal shape 9 alternate segments are always one-half block ahead of other 9, this feature being essential part of novel shield operation. Method compares favorably in cost with open-cut construction up to depth of 10 feet, beyond which tunnel method is cheaper.—*R. E. Thompson.*

Developing a Paved Invert Culvert Pipe. Eng. News-Rec., 105: 846–8, November 27, 1930. Asphalt paving was found to provide highest resistance to erosion by sand and grit. In development of paved invert culvert pipe, 116 asphalts were tested for ability to withstand shock, stability when hot, imperviousness, and abrasion. Life of asphalts under abrasion test employed varied from 6 to 4,440 hours, best asphalt having life more than 50 percent longer than second best. Average life of zinc coating under same conditions was 60 hours. Methods of testing outlined.—*R. E. Thompson.*

Public Water Supplies in British India. HAROLD E. BABBITT. Eng. News-Rec., 105: 678–82, October 30, 1930. Conditions in general relative to water supply in British India are discussed and supply systems of Bombay, Rangoon, and Calcutta are described briefly. No water works visited by writer had sufficient capacity to meet demand. Expedients adopted under these circumstances include intermittent supply, low pressure, and use of "no-waste" faucets on street hydrants (from which the poor secure their supply). Supplying water for less than 24 hours per day is inefficient method of diminishing consumption, as waste is increased to such extent that consumption may be greater than when supply is continuous. With intermittent supply, or low pressure, there is always danger of contamination. It has been found that even where mains are always under some positive pressure suction may be created in a service pipe due to high velocity in main, action being similar to jet pump. Most supplies are municipally owned. Nearly all cities are sewered, sewage being discharged directly into rivers without treatment, necessitating filtration of all supplies derived from such sources. Slow sand filters are widely employed and stand in high favor. Algae growths are a problem. All surface supplies are chlorinated. Lack of close laboratory supervision may partly explain rise in incidence of water-borne disease during rainy season, although habits of people are conducive to contraction of water-borne diseases through other sources than public water supply. The Tallah elevated reservoir, connected to Calcutta distribution system, is one of world's unique water works structures. It was built in 1911, has capacity of 11.25 million gallons, and is 320 feet square by 16 feet deep. Distance from ground to bottom of tank is 110 feet, and total weight of steel in tank and supports is 4,480 tons. In recent report on Calcutta supply, most of contamination is attributed to intermittent operation of pumps. Contamination has resulted principally from existence of: (1) surcharged or blocked sewers, saturating soil around water pipes with sewage; (2) water pipes laid beneath, through, and inside sewers; and (3) suction created in pipes under conditions of general low pressure, or local high velocities in distributing mains.—*R. E. Thompson.*

Parker Route Recommended for the Colorado River Aqueduct. Eng. News-Rec., 105: 854–6, November 27, 1930. Selection of Parker route for Colorado River aqueduct of Metropolitan Water District of Southern California was recommended by FRANK E. WEYMOUTH, chief engineer, in recent report which has been referred to board of review appointed last year. Initial construction cost, including interest, is estimated at $206,279,000. Route is 265.5 miles long and involves pumpage lifts totalling 1,523 feet. Cost of water would average $26.56 per acre-foot over 40-year period and $21.88 over 100-year period. Other routes investigated and reported on include Black Canyon, Bolls Head, and Picacho, which with Parker route comprised the 4 recommended by board of review, and also the All-American Canal and Bridge Canyon gravity line. Recommended plan calls for construction of diversion dam few miles above Parker, Arizona, at cost of $12,958,400, which would require consent of Arizona. Possibility of joint enterprise to serve Parker-Gila project in Arizona is considered. Alternative to dam would be clarification works at point of diversion, involving low-head pumping plant to lift water from river. With

dam, reservoir capacity provided would be sufficient to care for clarification and water could be diverted at considerably higher elevation. Aqueduct could be extended to Bridge Canyon at some future time, if warranted, thus partially eliminating need of pumping. Initial cost of Bridge Canyon gravity route is estimated at $557,000,000. [It is noted in Eng. News-Rec., 105: 1024, December 25, 1930, that Parker route was approved by engineering board of review, who recommend deferring construction of dam until several years after completion of Boulder Dam, in order to obtain advantage of silt control to be effected by that structure; and in Eng. News-Rec., 106: 204, January 29, 1931, that route was officially adopted by directors of District. Abstr.]—*R. E. Thompson.*

Steel Pipe Line in California. Eng. News-Rec., 106: 381, February 26, 1931. Prices bid on line of plate steel pipe, 12.7 miles long, for Hetch Hetchy water supply, from San Lorenzo to junction with existing 36-inch pipe at Newark, are given.—*R. E. Thompson.*

Transpiration Affects Streamflow. Eng. News-Rec., 105: 662, October 23, 1930. Flow measurements made on Rose Creek in connection with construction of water system for naval ammunition depot at Hawthorne, Nevada, showed striking diurnal variations. In July, 1928, when hourly readings were made, rate of flow in typical 24-hour period ranged from 67,900 gallons per day at 3.15 p.m., to maximum of 159,000 gallons at 6 a.m. Decrease in flow began just after sunrise and before there had been sufficient change in temperature to cause appreciable increase in evaporation rate. Explanation suggested by A. B. Purton, who made the observations, was, that as soon as sun rose transpiration from willows along creek bed commenced. Watershed above point of observation is relatively small and heavy growth of vegetation is concentrated near streambed.—*R. E. Thompson.*

Sampling for Suspended Sediment. T. W. Wood. Eng. News-Rec., 105: 1017, December 25, 1930. Sampling methods being employed in comprehensive study of sediment carried by Mississippi River and tributaries are described briefly. Several types of equipment are in use. One consists of corked bottle which is weighted and lowered to desired depth, then allowed to fill by withdrawing stopper by means of cord attached thereto. Another consists of ordinary milk bottle sealed with wax bottle cap. At desired depth a weight sliding on suspending cable is released, striking knife edge held by spring above bottle which perforates cap. Both are satisfactory, but are suited only to smaller and shallower streams. On main river, standard Mississippi River Commission sampler is employed, which consists of iron pipe fitted with flutter valves at both ends and suspended from one end by flexible steel cable. Weights hold pipe in vertical position as it descends and pressure of water opens valves, allowing free flow through pipe. At proper depth motion of pipe is suddenly checked, the valves close by their own inertia and are kept closed by reversed pressure as sampler is raised to surface.—*R. E. Thompson.*

Flow of Water Around Bends. William D. Mitchell and L. Harrold. Eng. News-Rec., 105: 739, November 6, 1930. Curves are given showing observed velocity of flow at point near middle of 180° bend on Potomac River, above junction with Savage River, which indicate that maximum velocity of flow in natural channel is near outer bank.—*R. E. Thompson.*

Flow of Water Around Bends. David L. Yarnell. Eng. News-Rec., 105: 939, December 11, 1930. Discussion of observations of Mitchell and Harrold (cf. previous abstract). Writer believes that entirely different velocity distribution would have been found at beginning of bend. In river bend of 180° with approach and discharge channels straight and uniform velocity distribution in channel approaching bend, water next to inner bank at beginning of bend travels faster than water next to outer bank because it has shorter distance to travel. Hence water surface next to inner bank tends to drop below elevation of water surface at outer bank. As water moves around bend the thread of maximum velocity shifts from inner bank at beginning of bend to outer bank at end of bend. Different bends may show entirely different velocity distributions, latter being influenced by many factors. Several reference are included.—*R. E. Thompson.*

Flow of Water Around Bends. Delbert B. Freeman. Eng. News-Rec., 106: 161, January 22, 1931. Explanation submitted for difference in water surface elevation between two points in same cross-section.—*R. E. Thompson.*

East Bay District Decreases Tax Levy. Eng. News-Rec., 105: 760, November 13, 1930. Expenditure and revenue of East Bay Municipal Utility District for coming year are estimated at $7,760,000 and $5,510,000, respectively, leaving balance of $1,850,000 to be raised by taxes, which will be taken care of by levy of 42 cents per $100 of assessed valuation throughout district. Last year the levy was 50 cents. It is predicted that levy will decrease annually. Present basic rate for small consumers, who constitute 97 percent of users, is 25.3 cents per 100 cubic feet, with 55 cents monthly service charge for ⅝-inch meter.—*R. E. Thompson.*

Regulating Devices for Rapid (Sand) Filters. Karl Henning. Gas-u. Wasserfach 73: 103–9, 1930. From Chem. Abst., 24: 2218, May 10, 1930. Description of various regulators for controlling supply of water to rapid sand filters, with illustrations and diagrams.—*R. E. Thompson.*

California Forbids Cross-connections. Western Construction News, 5: 10, 46, May 25, 1930. In conformity with the nation-wide "drive" to eliminate cross connections in water supply systems that may endanger public health, the State Board of Public Health adopted the following regulation April 12: Water added to any swimming pool or swimming pool piping system anywhere along its course, from a public water supply system, shall be added overhead with a free overfall and no cross connection shall be made between the swimming pool piping and the public water supply piping. A simple method of compliance is suggested in the form of a riser pipe on the circulating system (with

top above operating hydraulic head in pipe-line) with a free-flow feed through the top.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

Chlorine Resistance of Colon Bacilli and Streptococci in a Swimming Pool. W. L. Mallman and A. G. Gelpi, Jr. Mich. Eng. Expt. Sta. Bull., **27**: 3–16, 1930. "B. coli and streptococci accompanied by high bacterial counts were found when the Cl_2 content of the swimming pool was maintained at 0.1 to 0.2 p.p.m. The former developed a tolerance to free Cl_2 as evidenced by the fact that 0.5 p.p.m. of residual Cl_2 failed to destroy the organism either in the pool or experimentally in the laboratory with cultures isolated from the pool. Streptococci, although occurring in a pool maintained at 0.1 to 0.2 p.p.m. residual Cl_2, did not develop any Cl_2 tolerance. The occurrence of *B. coli* in swimming pools does not always represent dangerous pollution and should therefore not condemn the pool as unsafe. A better criterion of pollution should be devised. The *o*-tolidine test should never be relied upon entirely. A bacteriological test should be made at least twice weekly. The occurrence of streptococci in swimming pools with a residual Cl_2 content of 0.1 to 0.2 p.p.m indicates that the amount of Cl_2 is insufficient for safety. It seems that pools may be maintained at drinking water quality if the residual Cl_2 content reaches 0.5 p.p.m. each morning and never falls below 0.2 p.p.m. at any time. Search for streptococci and micrococci might be a better criterion of swimming pool safety than search for *B. coli*."—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

River Pollution and Fisheries. Surveyor, **77**: 1992, 402, March 28, 1930. A general review of the work of the Standing Committee on River Pollution, appointed by the British Minister of Agriculture and Fisheries, supplementing three interim reports. Efforts to remedy pollution have been by negotiation rather than by litigation. Collection of scientific information has been approached by chemical and biological surveys, both extensive and intensive, of polluted and unpolluted streams, which have been divided into three classes according to their degree of pollution. The committee's Advisory Board having recommended an intensive biological survey of a river with a definite, localized pollution, the river Lark was chosen for such a survey. With regard to beet sugar wastes, the committee states that the practicability of reusing "wash-water" and treating "process water" biologically has removed the last excuse for pollution by beet sugar factories. Resort to legal measures with this industry has been effective.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

The Sterilisation of the Drinking Water of the Towns of Saigon-Cholon (Cochinchina). A. Lambert. Trans. Far East Assoc. Trop. Med., **1**: 788, 1929. A ground water, of which the least bacterial count is 1,000 per cubic centimeter, forms the source of the drinking water supply of Saigon-Cholon (Cochinchina). A brief description is given of an arrangement for the sterilization of the water with calcium hypochlorite. The chlorination plant, which can be operated by a native, consists of three tanks, arranged one above the other, and a mixing basin. The first tank contains the chloride of lime solu-

tion which is diluted in the second, the third tank serving as a reserve. A glass float in the mixing basin regulates the admission of the standardized solution according to the raw water flow. A drinking water free from coli is produced.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Notes on Schistosomiasis in the Sudan. T. PARR. Journal of the Royal Army Medical Corps, **54**: 4, 261, April, 1930. Due to sparse population which is ignorant and primitive and to lack of transportation facilities, the geographical distribution of schistosomiasis in the Sudan is not definitely known, although it is a serious problem in Egypt. The development of the Sudan depends on agriculture which will necessitate opening large canals into the country from the Nile. The inexhaustible supply of potential hosts in the Nile (snails) will certainly spread infection to the irrigation canals and create a problem difficult of solution. In provinces where irrigation is under control scientific methods of approach to schistosomiasis treatment and control have met with considerable success. In non-irrigated provinces where water is scarce and rainfall is depended upon for the supply schistosomiasis is widespread as would be expected from the distribution of intermediate hosts. Both vesical and intestinal forms of the disease were observed, the former predominating.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Controlling Microscopic Organisms in Public Water Supplies. FRANK E. HALE. Water Works Engineering, **83**: 6, 353, March 12, 1930. The author has gone into great detail on the subject, and the article should be of great interest and value to those having similar problems. The following problems are discussed: (1) The by-passing of reservoirs; (2) early experiments in the use of copper sulphate; (3) lack of development of resistance to copper sulphate; (4) relation to health; (5) methods of application, i.e., spraying, rowboats and launches; (6) aqueduct continuous dry feed; (7) aqueduct continuous solution feed; (8) float continuous dry feed in lake; (9) treatment through holes in ice; (10) partial reservoir treatment; (11) consumption of copper sulphate by New York City; (12) changing point of draught; (13) deep draught; (14) aëration; (15) effect of normal dosage of chlorine; (16) superchlorination; (17) dosage; (18) increased chlorination of Croton supply; (19) start chlorination of Catskill; (20) pre-chlorination and filtration; (21) miscellaneous data; (22) crustacea; (23) excess caustic lime; (24) a table of dosages.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Regulating Chlorine Feed and Deciding Time for Tests. ELLIOT H. PARKS. Water Works Engineering, **82**: 11, 693, May 22, 1929. Four questions that commonly arise in chlorination of drinking water are answered by their author: (1) How much chlorine must be fed? Sufficient to insure residual chlorine after allowing a reasonable time for reaction. (2) How much residual chlorine should the water contain? From 0.1 to 0.3 p.p.m., depending on the nature of the water. Ground waters, as a rule, may contain a greater residual than surface waters without producing objectionable odors and tastes. (3) Where should the chlorine be applied to the water? Preferably to the filter effluent before entering the clear well, and, if practicable, a small secondary dose as

the water leaves the clear well. (4) How often should residual chlorine tests be made? At least once each shift. If the nature of the water or rate of pumping vary, so often as is necessary to insure a residual at all times. It is essential, also, that records be kept of time of making tests and results obtained.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Unusual Construction Problems Met in Two Far Eastern Water Works. M. F. Barnes. Water Works Engineering, 83: 10, 625, May 7, 1930. Water supplies of Bankok, Siam and Singapore, Straits Settlements illustrate problems and solutions to be found in Far East. Source of supply problems at Bankok, though located on river, so near sea that tides reach city and stream is further polluted by untold quantities of human waste and excrement that is dumped into it. The intake was finally established above the city and water conveyed by canal to city. A modern plant has been constructed, distribution system laid and the plant is under laboratory control. Value of plant repeatedly demonstrated in cholera epidemics. Different problems are presented at Singapore, where rain falls on the average of 180 days a year. A large catchment area was drawn on by impounding water behind a suitably placed dam. Dangers of tropics realized and suitable precautions were taken. Data are presented to show effects of protecting laborers from mosquitoes and pollution. Engineering difficulties are secondary as compared with problems offered by the morbidity and mortality risks. Overcoming of these difficulties makes this water supply development an outstanding achievement in Far East.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Operating Results from Well Arranged Iron Removal Plant. C. C. Foutz. Water Works Engineering, 83: 9, 557, April 23, 1930. The plant includes an aëration unit of 64 Sacramento type nozzles, a 1,200,000 gallon "aëration basin," followed by a mixing chamber having five horizontal passes and 30 vertical baffles. Following the mixing chamber are a 3,140,000 gallon settling reservoir, four 1 million gallons daily rapid sand filters, and a 1,500,000 gallon filtered water reservoir. Filters have average full load runs of fifty-five hours and wash freely in five minutes at 4000 gallons per minute. Alum dose is approximately 80 pounds per million gallons. Detention periods in aëration basin, seven hours; in settling basin, nineteen hours, based on normal operation of 4 million gallons daily. Raw water contains from 1.3 to 15.0 p.p.m. of iron, and filtered water 0.0 to 0.2 p.p.m. The plant cost $34,175 per million gallons daily capacity. Operating cost for five months ending January 31, 1929, was $13.43 per million gallons. (No full time labor is charged to iron removal, the duties of operation being distributed with steam pumping labor). —*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Water Supply and Sewerage of Large Japanese Cities. Harold E. Babbitt. Engineering News-Record, 104: 18, 729, May 1, 1930. Systems in Osaka (population 2,408,000), Tokyo (population 2,294,000), Nagoya, Kyota (population 750,000), Kobe (population about 673,000), Yokohama (population 645,000), Keijo (population 350,000) and Dairen (population about 150,000) are described. The author concludes "In the design of water and sewerage systems

the Japanese have followed and are abreast of Western engineering practice. Their designs have been made through the skill of Japanese engineers based upon studies of and inspections of works in Europe and America. The results obtained are object lessons of what can be accomplished in engineering design of study, observation, initiative and boldness."—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

Development of Sanitary Engineering in Poland. Z. Rudolf. Transactions of the First International Congress of Sanitary Technique and Communal Hygiene. The author mentions the fact that it has been possible to carry on normal work in sanitary engineering in Poland only since the European war. He discusses the progress made in legislation along those lines. Special attention is given to the sanitary betterment of small villages.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

Development of Sanitary Engineering in Czechoslovakia after the War. V. Dasek. Transactions of the First International Congress of Sanitary Technique and Communal Hygiene. From the end of the war to the present day municipal waterworks have been built at a cost of over 300,000,000 Czechoslovak crowns. Of these waterworks, attention is specially called to district waterworks of which it is necessary to remember at least the largest district waterworks on the Metuje for 84 communities and costing Kc 100,000,000, the waterworks for Usti n/Labem and district for 84,000 inhabitants, costing about Kc 50,000,000, for Teplice-Sanov and district, costing Kc 30,000,000, for Karlovy Vary (Karlsbad) and district, costing Kc 50,000,000. At the present time new waterworks projects, estimated to cost over 700,000,000 Czechoslovak crowns, are being considered.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

The Water Supply of the City of Athens from the Artificial Lake Marathon. Jean Vassilopoulos. Transactions of the First International Congress of Sanitary Technique and Communal Hygiene, Prague. Since 1840, the city of Athens was supplied with water from the old repaired waterworks of Hadrianus. After the war, the insufficient supply, caused by the increase of population, has induced the state to build an artificial waterworks. An American company has built near the famous fields of Marathon a gigantic dam of both rivers: Charadros and Varnava. The reservoir, having at some places the depth of 50 meters, has the capacity of 42,000,000 cubic meters of water. The water is conducted through a large tunnel into the reservoir near Athens. Before the inlet it is filtered and sterilised (method Buneau-Varilla, 0.05 mgm. of Cl to 1 liter of water). The old waterworks had daily supply capacity of 10 liters per capita. The new one delivers 100 liters.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

Water Supply in Czechoslovakia with a Special View to Watering Systems Arranged in Groups. Vaclav Cerny. Transactions of the First International Congress of Sanitary Technique and Communal Hygiene, Prague. The author discusses the supplying of drinking water in different regions and

municipalities of Czechoslovakia, and concludes that the group system, i.e., a common system for several municipalities (supported jointly by the state and the province) offers a practical solution to the problem of obtaining a satisfactory supply of drinking water in the country.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

Supply of Drinking Water by the Irrigation Method. Alois Opatrny. Transactions of the First International Congress of Sanitary Technique and Communal Hygiene, Prague. The superficial water filtered artificially is not suitable to be supplied to towns as drinking water, since in summer it is tepid, insipid and without flavor. The underground water, however, which is the only one capable of being used for uniform supply, occurs rarely in such quantities as would be sufficient for supplying cities. For this reason water obtained artificially by the underground irrigation method is now used. The superficial water is delivered to ditches or tanks or sandy deposits where it is left to soak up to the level of the underground water. At this time the bacteriological purification of water takes place. Then the mixture of infiltrated water and underground water moves horizontally and a transformation of superficial water into underground water is brought about in such a way that the physical and chemical qualities adapt themselves to the quality of underground water. The greatest changes take place in the temperature of water. This, however, is based on the condition that the water level is covered by a sufficient layer of deposits.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

New Pump at Springbank Station. V. A. McKillop. Canadian Engineer, 59: 1, 110, July 1, 1930. The water supply of London is pumped from spring water collecting ponds to a 16 m.g. reservoir, which feeds the distribution system by gravity. The three original pumping units, two of which had been in service 18 years, had fallen off in capacity, necessitating the operation of two pumps at certain hours. A new motor-driven centrifugal pump has been installed which will deliver the required amount of water operating about 20 hours each day, enabling the station to be shut down during the period of peak load on the electrical department. It is estimated that the new pump will effect a saving of $400 per month or sufficient to pay for the installation in the first year. One of the old pumps was transferred to the Ridout Street Station for fire service and the other two retained for emergency use.—*A. W. Blohm* (*Courtesy U.S.P.H. Eng. Abst.*).

The Water Supply Scheme of Yallourn (Victoria). L. T. Guy. Proc. First Commonwealth Conference on Public Health Engineering, Service Pub. 2, Dept. of Health, Commonwealth of Australia. This paper describes the development of the public water supply for the new township of Yallourn in the state of Victoria which was placed in operation early in 1924, at which time it was estimated that the population of the township would exceed 1000. The design of the waterworks plant is based upon an ultimate population of 3000. The waterworks system installed involves the pumping of raw water from Latrobe River to a raw water basin at an elevation of about 500 feet above sea level through a 10-inch diameter wood stave pipe. The length of pipe is

about 3000 feet and the actual lift being about 370 feet. The water thence passes into a regulating basin of 750,000 gallons capacity, which allows for some sedimentation. The treatment adopted consists of dosage with aluminium sulphate, followed by sedimentation for a period of nine to fifteen hours. The sedimentation ponds or basins, of which there are three have dimensions of 40 feet in length, 20 feet in width and 6.5 feet in depth with suitable baffle walls. They allow for a retention period of six hours at the maximum designed capacity. Tests which have been made subsequent to the plant being placed in operation have indicated that these basins would not provide a thoroughly satisfactory water when operated at their full designed capacity unless additional treatment with an alkali to adjust the pH value of the water to the optimum value for coagulation and sedimentation and unless a mixing device to improve floc formation were installed. At present, good results are stated to be obtained with an average dose of aluminium sulphate of about 2.0 to 2.5 grains per gallon as it is possible to retain the water in the sedimentation ponds for periods up to thirteen hours at times of turbidity. There is also a storage reservoir of 1,000,000 gallons capacity which is about two days maximum supply. Chlorination of the water was not provided in the design of the plant, although it was recognized that such treatment might be necessary to supplement the processes adopted. It is stated, however, that after three years of operation it is not considered necessary to adopt any further purification treatment.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Hartford Water Department Notes. C. M. SAVILLE. Public Works, 61: 1, 32, January, 1930. An extract from the 75th Annual Report of the Board of Water Commissioners of Hartford, Conn. The construction of rapid sand type pre-filters to increase the capacity of present slow sand filters is being considered. A pitometer survey detected leaks aggregating over 400,000 g.p.d., methods described. Day labor work appears preferable to contracts. Results given on tests to determine coefficient of friction in large concrete and C. I. pipe lines. The Nepaug Reservoir, capacity 7,240,000,000 gallons has required 10 years to free itself of the effect of organic matter on the bottom of the new reservoir. The duty of water boards to make progressive plans to keep pace with demands upon the system at a minimum of expense is emphasized.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Dissolved Oxygen in Relation to Anopheles Breeding. M. O. T. IYENGAR. Indian Journal of Medical Research, 17: 4, 1171, April, 1930. The remarkable diurnal variations in the dissolved oxygen concentration in water of ponds has been studied in full detail. The oxygen concentration reaches the lowest level for the day at 6 a.m. and reaches the highest level between 2:30 and 3:30 p.m. These fluctuations are natural phenomena observed invariably during each of the days during which these observations were carried out and in every pond investigated. They are caused by the process of oxygen production through photosynthesis during day-time and the using up of oxygen through respiration by the plant and animal life of the pond throughout the day and night. The highest oxygen concentration of the pond water is reached at a time when sunshine is greatest and when the temperature of the water is also at its high-

est. Minute algae play a very large part in the increase of the dissolved oxygen concentration of the water. The dissolved oxygen tests were made by Winkler's method with slight modifications. The waters tested were not subject to any sewage pollution and did not contain any trace of nitrites. The exact technique used in the collection of samples and the dissolved oxygen determination is given.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Report of the Board of Purification of Waters Made to His Excellency the Governor for the Years 1928 and 1929, State of Rhode Island and Providence Plantations. The Board was originally organized in 1920. The law places upon the Board the entire responsibility for the regulation of pollution. This report gives the Board's disposition toward residential sewage discharges, manufacturing wastes, and oil discharges.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Meeting Emergency of Drought in a Ground Water Supply. WYNKOOP KIERSTED. Water Works Eng., **83**: 5, 315, February 26, 1930. When Lake Abilene, which supplies the city of Abilene with water, was exhausted, the emergency was readily met by excavating pits into the gravel deposits below Lake Abilene dam. Later additional wells were also excavated above the dam and an adequate supply was secured. Investigations indicated that the water in the gravel deposits below and above the dam came from Lake Abilene and it was at first estimated that 30 percent of the water in the lake had been used by the city, 23 percent had been lost by evaporation and 47 percent was lost by leakage. Later the loss by leakage was estimated to be about 28 percent. The alkalinity indicated that the water in the gravel was diluted by lake water. —*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Sanitary Water Analysis. R. L. LAYBOURN. Fifth Annual Report of Missouri Water and Sewerage Conference. Water supplies which are safe from a bacteriological standpoint usually have fairly satisfactory physical and chemical characteristics. The collection of a representative sample, the test for *B. coli* and plant laboratories are described in detail.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

St. Louis—New Howard Bend Water Works. JOHN D. FLEMING. Fifth Annual Report of Missouri Water and Sewerage Conference. The article includes a detailed history of the events leading up to the actual construction of the new water works at Howard Bend in St. Louis, Mo. In 1915 it was decided to build a plant with a covered storage reservoir of 100 m.g. capacity and which in some of the units would be capable of handling 200 m.g.d., others 100 m.g.d. and still others only 55 m.g.d. The cost was estimated at $12,000,000. The authorizing bond issue was passed in February, 1923, and within four months the necessary land and rights of way had been secured and the first of some fifty general contracts, entailing the expenditure of practically the full $12,000,000, was awarded. A description of the various features of the plant including a carbon dioxide charging basin, Dorr clarifier and sludge pumps is included.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Description of the Arrangement and Operation of the St. Joseph Water Purification Plant. Jos. Bumbacher, Jr. Fifth Annual Report of Missouri Water and Sewerage Conference. The purification plant includes eighteen gravity type filters with a total rated capacity of 14.8 m.g.d. and three settling basins, with combined capacity of 12 m.g.d. The supply is pumped to open storage reservoirs of 12 m.g.d. capacity from which it is delivered by gravity to the city.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Home Made Filter Plant Appliances. E. E. Wolfe. Fifth Annual Report of Missouri Water and Sewerage Conference. A description of several inexpensive filter plant appliances such as rate of flow indicator, wash tanks and reservoir elevation gauges which were made to supplement rather than to displace the standard manufactured equipment installed in the new filter plant at Hannibal, Missouri. It is also pointed out that such enterprise is of value to operators in that it may lead to an increased personal interest in the plant.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Draft of Bill for Protection of Mineral Springs. J. V. Hrasky. Trans. First International Congress of Sanitary Technique and Communal Hygiene. In his paper the author discusses in the first place the importance of mineral springs from the point of view of public welfare and describes in detail what economical advantages on the part of the state are obtained by the improved conditions of health of its citizens, by the increased affluence of visitors, by raising the level of the spa and spring industry, and finally by increasing the income of the state. He discusses the main principles of the Draft of a Bill for protecting mineral springs and attaches a literal reading of same worked out by a commission of experts elected by the Central Association of spas and mineral springs.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Care of Cleanliness of Water and Public Health in the Water Legislation. Jaroslav Cerny. Trans. First International Congress of Sanitary Technique and Communal Hygiene. The author submits a survey of the legislation concerning care for cleanliness of water and public health welfare in Czechoslovakia, France, Italy, Spain, Switzerland, Austria, Hungary, Prussia, Saxony, Bavaria, Wurtemberg, Baden, Poland, Roumania, and England. International congresses are the best organs of media for exchange of ideas and information of individual states and even though they do not have executive powers, still with their suggestions and objections they can give directions not only to science and economical life but also to administration.—*A. W. Blohm (Courtesy U.S.P.H. Eng. Abst.).*

Determination of the Salt Error of Indicators and the Accurate Estimation of the pH of Solutions by Colorimetric Methods. Saunders, J. T. Proc. Cambridge Phil. Soc., 1923: 1, 30. Treats of buffer solutions and mixtures for colorimetric pH estimation and of corrections necessary, as worked out by Sörensen and by others. Series of buffer mixtures can be prepared with intervals as small as pH 0.02 between successive members, but only with certain indicators, such as the sulphonphthaleins recommended by Clark and

Lubs, can such small differences be read, and even with them, not throughout their whole range of color change, or, as the French call it, virage, but only over that part of it where color change is most palpable. List of indicators and their ranges is given and range of cresol red discussed. Salt error is explained and Sörensen's method for determining it is described and criticised, table of his corrections being included. Michaelis and Krüger showed that depression of pH by salts is caused by the metallic cation and not by the anion, indicating that buffer solutions should, when mixed, always have same equivalent concentration of metallic cations. Salt error of indicators in range pH 6.60 to 7.00 can be easily discovered from results obtained with them. Work of Wells is discussed and curve deduced giving salt error of cresol red for any difference of concentration between buffer mixture and solution of unknown pH. Simple method of determining salt error of any other indicator by comparison with cresol red is outlined. Carbonate buffers and the determination with them of salt errors are described, diagram of the apparatus, Hasselbalch's formula, and other data being included. Bibliography appended.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Limits of Applicability of Indicators in Simple pH Determinations. Eisenbrand, J. Pharm. Ztg., 1929, **74:** 989 and 1009; Brit. Chem. Abst. A, 1929, **1157.** Detailed discussion of sources of error. Salt error in buffered solutions is considered for various indicators: it will vary with different indicators and also with concentration and nature of the salt. Calculations are given of errors introduced by various concentrations of sodium and potassium chloride from N to 5N. Degree of dissociation of indicator is chief source of error with unbuffered solutions. Limited applicability of indicators with very small dissociation constants and of neutralized indicator solutions is discussed. Colored indicators are unsatisfactory for measuring pH in unbuffered solutions. pH of indicator itself can be ignored only where its concentration is exceptionally low as when fluorescent indicators are used in conjunction with quartz lamp.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Apparatus for the Estimation of Carbon Dioxide in Water Supersatured with Carbon Dioxide. Chemisches Laboratorium Welwart. Chem. Ztg., 1929, **53:** 749. For mineral and aërated waters. Small hole is made in tube of cork borer to come just below cork of the sample bottle. Grip of borer is fixed half an inch down the tube, so that glass tube with stop-cock can be fixed with sealing wax to its upper end. Rubber joint is not recommended, as rubber is permeable by carbon dioxide. Borer is driven into cork of bottle until hole is just below the cork, glass tube is connected to the carbon dioxide absorption apparatus, and stop-cock slowly opened: bottle is placed in water-bath which is slowly heated. Cock is then closed, and bottle cooled and well shaken, so that residual carbon dioxide in air-space is reabsorbed by water. The carbon dioxide driven off is weighed, or titrated, and residual carbon dioxide in water is titrated with N/10 caustic soda and phenolphthalein, after Tillmans.—

M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).

A Method of Quantitative Examination of Bacterial Plankton. CHOLODNY, N. Zbl. für Bakt., II, 1929, **77**: 179; Wass. und Abwass., **1929**: 26, 127. Water sample is preserved with formalin and filtered through membrane of pore-width from 1 to 2μ. When only small bulk remains on filter, about 0.05 cc. is placed on slide and dried. Slide is then stained with erythrosine, stained area measured, and number of bacteria counted with ocular net-micrometer. Number of bacteria in 1 cc. of water can thus be approximated with sufficient accuracy. Numbers obtained are very much higher than by usual pour-plate method. Bacterial contents formerly taken as characteristic of poly-, meso-, and oligosaprobic zones, are shown to be far below their respective actual contents. Quantitative relation between morphologically different types of bacteria and preponderance of certain forms are immediately recognizable. Another advantage is that formalin-treated samples remain unaltered for some time. Weaknesses of method are that it shows no distinction between permanent and transient forms; nor between living and dead bacteria.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Dilution Method for the Colorimetric Determination of pH in Coloured Solutions. THOMPSON, F. C. and ATKIN, W. R. J. Soc. Leather Trades Chem., **1929**: 13, 297; Brit. Chem. Abst. A, **1929**: 1157. Series of dilutions of original solution are prepared in which pH values can be determined colorimetrically and plotted against logarithms of corresponding concentrations, pH value of original solution being then determined by extrapolation.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Determination of Hydrogen Ion Concentration by a Modified Colorimetric Method. CAMERON, D. H. J. Amer. Leather Chem. Assoc., **1929**: 24, 76; Chim. et Indust., **1929**, 22, 486. Method requiring no permanent color standards, in which essential feature is addition of 0.2 *N* sodium hydroxide to buffer solution, is fully described. Indicators and buffer solutions used are those recommended by CLARK, of which pH fields and values, respectively, are given.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

Determination of the Oxidizability of Drinking Water. HUBER, P. Mitt. Lebensmitteluntersuchung u. Hyg., **1928**: 19, 153; Z. für anal. Chem., 1929, **77**: 235. Blank with 100 cc. of distilled water under experimental conditions should always be carried out. Oxidizability, x, expressed as mgm. permanganate per liter of sample is then given by formula

$$x = \frac{31.6 \times (T - a - b)}{T}$$

where T = oxalic acid titer of 10 cc. of $0.01 \times N$ permanganate solution used; a = cc. permanganate solution consumed in final KUBEL titration (of excess oxalic acid); and b = cc. permanganate consumed in blank. In presence of much gypsum and magnesium sulphate, determination of dry residue total solids will give unreliable values unless temperature held constant. Drying should be at 180°, at which temperature gypsum is water free, and magnesium carbonate retains only 1 molecule of water and has not begun to dissociate. Residue obtained at 180° can, however, not be regarded as accurate sum of constituents actually present.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Suspended Matter in the Estimation of the Turbidity of River Water. MASSINK, A. Supplement II, Ann. Rep. of State Bureau for Drinking Water Supplies (Holland) (Rijksbureau voor Drinkwatervoorziening), 1928: 70. Reprinted from Verslagen en Mededeelingen betreffende de Volksgezondheid, September, 1929. Gravimetric determinations of suspended matter in river water at various stages of purification were accompanied by estimations (by MIDDENDORP's method) of turbidity of same samples. Comparison of results led to conclusions (1) that gravimetrical determination of suspended matter cannot be replaced by turbidity determination; (2) that turbidity determination before filtration gives useful results; and (3) that there is a correlation between turbidity of prefiltered, and that of fully filtered water. It is also noted that high turbidity usually accompanies high bacterial content, so that turbidity determination may be used as a rapid method of obtaining a provisional indication of the bacterial content of filtered water. It is suggested that further investigations of this subject at river water-works are desirable. Tables and graphs of the results of experiments and German, French, and English summaries are given.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Studies of the Alteration of Bacterial Flora on the Storage of Polluted Surface Waters in the Tropics, with Special Reference to Clemesha's Method for Determing the Age of Pollution. HOLWERDA, J. K. Mededeel. Dienst. Volkegezondheid Nederl.-Ind., 1928, 17: 410; Zbl. ges. Hyg., 1929, 19: 6; Wass. u. Abwass., 1929: 26, 98. According to several investigators, danger of infection in water can be better estimated by difference between glucose and lactose titers and by rate of disappearance of lactose-fermenting types, than by warm-blood coli-titer. After discussing titer estimation and methods of isolating lactose fermenters, author describes experiments with strongly polluted river water stored in glass-covered reservoirs and in closed reservoirs protected from light. Generally it appeared that alteration in bacterial flora depended chiefly on direct and indirect influence of sunlight; but also on selective action of higher organisms. Appearance of differences between glucose and lactose titers on storage in reservoir is not general.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Fresh-Water Fauna of New Caledonia. Cockerell, T. D. A. Science, 1929, 70: 378. Fauna and flora of New Caledonia suggest that it is part of an ancient land mass possibly separated in Mesozoic times. Fresh-water fauna are limited. Forms described by Weber and Beaufort come undoubtedly from the sea. New form of *Galaxias* appears to be a very old migrant from the ocean much modified. A form of Mollusc *Hemistomia caledonica*, described by Crosse, may have same origin, having resemblances to both fresh and salt-water groups. Island is rich in genus *Physa*, but this genus requires re-investigation before its origin can be established. Recorded fresh-water bivalves include one endemic species, *Cyrena sublobata Deshayes*, to which author adds mytiliform shell, *Modiolaria bourailensis n. sp.*, which he describes, discussing its relationship with fresh and sea-water types.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Biology of Lakes in Kenya. Jenkins, P. M. Nature, 1929, 124: 574. Summarizes results of investigation of lakes Baringo, Nakuru, Elmenteita, Naivasha, and a small crater lake in Rift Valley in Kenya. Though at higher altitudes temperature conditions approached those of temperate regions, diurnal changes were more marked. Lake Naivasha was least abnormal, containing planktonic Entomostraca and Rotifera, phyto-plankton (a species of *Microcystus* and various diatoms), zones of aquatic plants, and numerous fish, while bird life was varied. Alkali reserve (expressed in normality) was 0.004 400 p.p.m. alkalinity], but base was sodium, not calcium. In increasing concentration, this alkalinity effects reduction in fauna and flora which is shown in the other lakes where alkalinity is higher. These are characterized by abundance of blue-green algae and absence of shore vegetation. Flamingoes are constant dwellers on these lakes and author makes some observations on their food.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Flow of Swedish Rivers. Nature, 1929, 124: 634. Note on paper by G. Slettenmark in Meddelanden från Statens Meteorologisk-Hydro-grafiska Anstalt, 4: No. 5. Charts are published illustrating the amount of discharge of Swedish rivers, giving mean flow of all rivers above a certain discharge, mean flow of chief rivers at high and low water, and area of lakes in drainage area of each river basin. Seventy-four per cent of total drainage of Sweden is supplied by fourteen rivers. Tables of detail of flow of principal rivers are given.—*M. G. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Estimation of Oxygen in Waters Polluted by Effluents of Certain Composition. Haase, L. W. Gesund. Ing., 1929: 52, 846. Effluents from sulphite pulp process remove very rapidly all evidence of presence of oxygen in a stream as shown by Winkler's method. This is due to the affinity for oxygen being stronger in sulphite than in manganous hydroxide used in determination. Under normal stream conditions, however, oxidation of sulphite proceeds extremely slowly; so that it is insufficient to account for apparent disappear-

ance of oxygen. Author makes preliminary announcement of electrometric process by which oxygen content of liquids can be estimated under any conditions of external influence, or composition. Waters in which no oxygen is discoverable by usual process can be shown by this process to contain oxygen. —*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Determination of Hardness in Water by Means of a Soap Solution. Chemisches Laboratorium Welwart. Chem. Ztg., 1929, 53: 728. Summary is given of G. Bruhn's observations on determination of lime and magnesia hardness in water by means of the French soap solution (Chem. Ztg., 1929: 48, 469). Same results are obtained with Clark's soap solution and were mentioned by W. Kalmann before 1908, when Bruhns made his observations, in his Kurze Anleitung zur chemischen Untersuchung von Rohstoffen und Produkten der landwirtschaftlichen Gewerbe und der Fettindustrie. 2nd edition, 1906.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research, Board, Summary of Current Literature*).

Epiphytic Investigations in Lake Balaton. Cholnoky, B. V. Intern. Rev. ges. Hydrobiol. u. Hydrog., 1929: 22, 313. Simple method used by Thomasson for examining microphytic growths was applied to study of epiphytes of phragmites-plants in Lake Balaton. Author ascribes lack of measurements of benthos in lakes, ponds, and the sea to want of some such method. Methods for removing plants from deep water, examining shells, and recording results are described; list is given of 150 organisms examined, with note on occurrence of each. Detailed and graphically illustrated account of place and depth distribution of those organisms which were regarded as typical epiphytes of phragmites-plants, as distinguished from plankton, is given. Lake Balaton does not show vertical zoning characteristic of many lakes, and it is suggested that this zoning may be due, not to physical properties, but to some unknown influence on density of plant growth. In very large number of epiphytic diatoms, reproduction by auxospores was observed and author suggests that this may be influenced by temperature.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Plankton Population of the Weddell Sea, According to the Results of the German Antarctic Expedition, 1911-12. V. The Polychaetes of the Weddell Sea. Augener, H., and Lohmann, H. Intern. Rev. ges. Hydrobiol. u. Hydrog., 1929: 22, 273. Ground forms were almost entirely larvae of *Herdmanella gracilis*. Over deep water, larvae of benthonic worms appeared in the south. Most common pelagic form was *Pelagobia longicirrata* which appeared in all parts and was only polychaet to appear regularly and in some numbers. Larvae were found abundantly near coast during summer, but numbers were, in general, too small to enable conclusions as to seasonal or latitudinal variations to be drawn. Greatest number of polychaets were caught at depths of between 60 and 200 metres. Map of region, tables of catches and of depth dis-

tribution, and full descriptions of specimens are given.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

How Pennsylvania Meets the Stream Pollution Problem. THEO. B. APPEL. Water Works Eng., 84: 17, 1201, August 26, 1931. Sanitary Water Board classified streams as follows: A, no pollution present; B, more or less polluted, but capable of improvement; C, intensely polluted and can be used only for drainage canals. Survey disclosed 25,000 miles as class A; 50,000 miles as class B; and 25,000 miles as class C. Most dangerous type of pollution was domestic sewage. Industrial wastes must be studied as separate problem. Board has induced certain industries to coöperate in study of their own waste waters. Leather tanning industry was first with which Board was able to work out a coöperative agreement. After 6 years of research, practical and efficient method for treatment of tannery wastes was developed. Agreement was signed with coke industry, under which they would notify Board of any accidental spill of phenol wastes. Bituminous Coal Mine Drainage Board of Pennsylvania was organized to consider problems of this industry in spite of fact that coal mine discharge is excepted from Purity of Waters Act. In survey of the Schuylkill, only about two dozen industrial establishments were found to be significant contributors of pollution. Mandates were issued to all municipalities and industries polluting to prepare comprehensive plans and proceed with construction. In four cases it was necessary to invoke assistance from Department of Justice. One packing company came to terms in face of threatened suit. In 25 years, graph of alkalinity at Pittsburgh has shown 45 degree drop and it is now dangerously near line of abscissae. With each year, Pittsburgh water officials are compelled to use greater quantities of soda ash to neutralize acidity. Plans are being made to eliminate this difficulty, although much of the acidity originates from without the state.—*Lewis V. Carpenter.*

Water Supply, Sewage Treatment and Refuse Disposal in 1930. H. BURDETT CLEVELAND. Public Works, 61: 12, 26–7, 1930. Review of developments in these public utilities is given.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Aëration Corrects Taste and Red Water. K. W. GRIMLEY. Public Works, 61: 12, 29–30, 1930. Spring water with a pH of 5.2 and CO_2 content of 46 p.p.m is passed through coke aërator which raises pH to 6.5 and reduces CO_2 to 5 p.p.m. As final step, water is treated with Na_2CO_3, to bring pH to 7.4.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Work Done by Hartford Water Board. Anon. Public Works, 61: 12, 55–6, 1930. Pipe line consisting of 16,925 feet of 42-inch, and 2075 feet of 36-inch, reinforced concrete pipe of so-called cylinder construction was built. New mains are sterilized by introducing chlorine gas directly into main by means of portable chlorinator.—*C. C. Ruchhoft.*

The Design of Earthen Embankment, Masonry-Lined Distribution Reservoirs. Chester A. Smith. Water Works and Sewerage, 78: 37–42, 1931. Following factors are discussed: excavation and embankent slopes, embankment materials and construction, protection of outlet pipes, reservoir lining, reinforcement, expansion joints, waterproofing, underdrains, storm drains and overflow, and costs. Tables and sketches are included.—*C. C. Ruchhoft.*

Recent Developments in Chlorination. Francis D. West. Public Works, 61: 12, 23–4, and 76–8, 1930. Importance of thorough distribution of chlorine is emphasized; prolonged sterilizing effect obtained by formation of chloramines is discussed; and it is indicated that chlorine is more efficient as a disinfectant in alkaline solution. Effectiveness of chlorine as an algae-cide can be increased by traces of copper.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Settling Basins for Coagulated Water. John R. Baylis. Water Works & Sewerage, 78: 61–65, 1931. Types of settling basins in use, their construction and suitability for various conditions of water are described.—*C. C. Ruchhoft.*

Cost of Water Purification at St. Louis, Mo. Anon. Water Works and Sewerage, 77: 429, 1930. Average unit cost of purification per million gallons, based on consumption for period 1920 to 1930, at Chain of Rocks plant was \$10.79. Cost for chemicals was 62.4 percent and for labor, 4.6 percent. Remaining 33 percent was for operating, maintaining, and repairing combined purification equipment.—*C. C. Ruchhoft.*

Construction of the Moccasin Dam. Anon. Public Works, 62: 2, 32, 1931. This dam will create the Moccasin re-regulating reservoir, to be used in connection with generation of power by Hetch-Hetchy water supply system of San Francisco. Dam is of earth and rock fill, with concrete core wall. Construction details are given.—*C. C. Ruchhoft.*

The 1930 Drought and Public Water Supplies. Isador W. Mendelsohn. Public Works, 62: 3, 59, 1931. Traces effect of drought on shortage in water supplies in a number of eastern states. Credit for prevention of consequent outbreaks of water-borne disease is ascribed to prompt emergency action of state sanitary engineers in coöperation with local authorities. It is recommended that complete data be collected pertaining to the drought, that sanitarians may be better prepared in the future.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Water Supply and Sewage Disposal in Cairo, Egypt. H. Heukelekian. Public Works, 62: 3, 33–4, 1931. At Cairo, Nile River water is given primary sedimentation, treated in modern rapid sand filter plant, and chlorinated. Daily tests show absence of lactose fermenters in 50-cc. portions of tap water 95 percent of the time. Difficulties with algae, filter clogging, and tastes are encountered. Cairo's sewage is settled in Travis tanks and effluent used for irrigating 1400-acre sewage farm. Sludge from Travis tanks dries in the desert within four days and is sold for fertilizer.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Settling Basins for Coagulated Water. JOHN R. BAYLIS. Water Works and Sewerage, 78: 85–90, 1931. As exemplifying continuous sludge-removing devices now coming into use, Dorr clarifier has slowly revolving rakes located very close to floor which gradually move sediment toward the center. It is used in water and sewage plants both in preliminary settling tanks and for removing coagulated material. It is best economy to settle coagulated water below turbidity of 20. Flow through settling basin may vary from 0.5 to 5.0 feet per minute.—*C. C. Ruchhoft.*

Watch for Flocculated Matter Passing the Filter Beds. JOHN R. BAYLIS. Water Works and Sewerage, 77: 47–20, 1930. In cold weather, flocculated matter has tendency to pass through the filter and filtered water should be watched for this condition. Material that passes through consists of particles of coagulum of from 0.01 to 0.02 mm. diameter, resulting from disruption of larger flocculated masses which are forced through very small openings between sand grains when loss of head becomes high. Such particles may constitute great potential danger to bacterial safety of the water, for chlorine cannot always penetrate to destroy bacteria contained in them. "After precipitation" does not exist as such, but is due to coagulated matter passing through filter bed. Turbidity of filtered water should not exceed 0.2 p.p.m. Floc detector is described.—*C. C. Ruchhoft.*

Training Operators for Filtration Plants in Small Towns. A. E. CLARK. Public Works, 62: 2, 57, 1931. Various State Departments of Health are using one of three following plans for training and assisting water purification works operators of small communities: (1) conference of operators; (2) conference and short school in combination; (3) short school. Conference plan is better adapted to states having a predominance of technically trained operators, while short school plan works better in states with more non-technical operators.—*C. C. Ruchhoft.*

Taste Elimination with Powdered Activated Carbon. E. A. STEARNS. Water Works and Sewerage, 78: 11–12, 1931. Seasonal tastes and odors were successfully eliminated from water supply of Hamburg, N. Y., by use of powdered activated carbon. Special feed machine was developed, hopper of which contained two screw conveyors on vertical shaft, lower feeding downwards and upper feeding upwards. This is necessary to prevent arching trouble. Dry carbon falls to small tank and is carried by water through vertical outlet to small pump running at 1425 r.p.m. which introduces colloidal mixture into settled water line under pressure. Dosage varies from 0.05 to 0.075 grains per gallon. Treatment includes prechlorination to give residual of 0.4 p.p.m. and secondary chlorination which maintains residual of 0.1 p.p.m. —*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Design of Mixing Basins. JOHN R. BAYLIS. Water Works and Sewerage, 78: 13–21, 1931. Mixing basins constitute comparatively recent addition to water filtration plants and their design, accordingly, varies greatly. Hydraulic data concerning their operation are rather meager as yet. Following types

of mixing devices are discussed in detail: (*a*) chemicals applied to raw water conduit; (*b*) horizontal baffles; (*c*) vertical baffles; (*d*) mechanical mixing; (*e*) spiral inward flow; and (*f*) special types, such as hydraulic jump and air agitation. Suitable velocities for various types are recommended. Method is given for computing power costs in each instance.—*C. C. Ruchhoft.*

Measuring the Volume of Coagulated Matter Passing Filter Beds. John R. Baylis. Water Works and Sewerage, **78**: 33–6, 1931. Two methods for measurement of suspended coagulated matter are presented. First involves use of special floc detector enabling filter effluent to be compared with suitable standards, for preparation of which two methods are given. In second method, volume of sediment is directly read off after centrifugation in Goetz tubes. Former method is recommended when amount of coagulated matter is small: it is then applicable alike to filtered water and to that which has been settled only. Centrifuge method is applicable to all coagulated waters prior to sedimentation and to most settled waters. It is not recommended for waters containing less than 75 volumes of flocculated matter per million volumes of water. —*C. C. Ruchhoft.*

Water Supply Increased by Use of Infiltration Gallery. A. A. Weiland. Water Works and Sewerage, **78**: 1–2, 1931. Inadequate water supply of Castle Rock, Colorado, was supplemented by laying 2,800 feet of perforated pipe. Collection system includes main line of 2,400 feet laid parallel to creek and cross line of 400 feet at right angles thereto. Further supply was obtained by driving several 4-inch vertical pipes which connected with perforated horizontal line. Trouble from quicksand was eliminated by using graded gravel on top of perforated lines and by keeping these lines free as construction progressed.—*C. C. Ruchhoft.*

Precipitation Records and "Effective" Rainfall. Alfred S. Malcomson. Water Works and Sewerage, **78**: 60, 1931. Apparatus for measuring rainfall consists of rain-gauge and support. Gauge has four parts: (1) receiver, which has circular exposure of 8 inches in diameter and discharges through funnel into (2) measuring chamber, which supports receiver: measuring chamber is 20 inches deep and so proportioned that it magnifies depth of rainfall by ten; (3) measuring stick, or scale, is graduated in inches and tenths: reading must be divided by ten: measuring chamber has capacity of 2 inches of rainfall and any excess passes into (4) overflow chamber. Snowfall is reported both as inches of rainfall and as inches depth of snowfall. Former is determined by converting the snow to water. Approximate times of beginning and ending of rain and snowfalls are recorded. In connection with rainfall records, snow blanket should be taken into account, becoming "effective," as its equivalent in rainfall, only when it melts.—*C. C. Ruchhoft.*

The Colorado River Aqueduct. Julian Hinds. Water Works and Sewerage, **78**: 157–60, 1931. The Hoover Dam, creating storage space of 30,500,000 acre-feet, is proposed as means of regulating flow of Colorado River, both to make it available for beneficial use and to afford protection against floods. It

will also release a large block of power. Dependable flow of river will supply water to Metropolitan Water District of Southern California, composed of 14 cities with population of 1,699,000. Diversion of 1,500 second-feet will double present supply. Water will be brought through 250-mile aqueduct across region of barren mountains, separated by deep valleys. It will have to be pumped to overcome high elevation and friction in distribution lines. Point of diversion will be at Parker, Ariz. Total length of route is 267 miles, of which 74 miles will be lined canal; 80 miles, cut and cover conduit; 94 miles, tunnel; and 19 miles, pressure lines, inverted siphons, etc. Water level in Colorado River will be raised from low water level of 378 feet to elevation of 450 feet by concrete diversion dam. It will then be raised by two pumping plants into aqueduct at 989 feet elevation. Total pump lift will be about 1,500 ft. Power for pumping will be secured from plants to be constructed at Hoover Dam and at Parker.—*C. C. Ruchhoft.*

Operation of N. Y. Water Supply System. William W. Brush. Water Works and Sewerage, **78**: 97–9, 1931. Since chlorination is used for sterilization, it has not been necessary to purchase land beyond a strip about 500 to 1000 feet around each reservoir. Inspectors patrol watershed to watch for possible sources of contamination. The New York State Department of Health does not prohibit bathing in waters from which public supplies are taken. Boating, fishing, and ice-cutting are allowed by law with regulations. Where tributary streams are polluted, department installs a chlorinating plant. Department carries out reforestation enterprises. Microscopic growths are controlled by copper sulphate treatment. Aqueducts are not cleaned; chlorination helps to remove and prevents growths. Wherever a sewer, or water pipe, crosses an aqueduct special construction is resorted to. Aërators are used at Ashokan and Kensico reservoirs. All water is chlorinated at least once, certain well supplies, where conditions do not warrant it, excepted. Distribution reservoirs are being enclosed by wire link fences. Seagulls frequenting the reservoirs are shot. New mains are installed by corporate stock funds. Cast iron pipe is now lined with cement surfaced with coal tar, or asphalt. Chlorine, or chloride of lime, is used to sterilize new mains. Electric power is being substituted for steam in pumping. High pressure can be supplied on request by the fire department.—*C. C. Ruchhoft.*

Fundamental Principles of Well Construction. A. G. Fiedler. Water Works and Sewerage, **78**: 94–6, 1931. In selecting location, study should be made of geological formation, by analysis of nearby wells and by drilling. Principal features of sanitary significance are (1) nearness of existing sources of pollution, (2) danger from flooding, and (3) character, depth, and water-bearing properties of formations to be tapped. Type of well must depend upon conditions of service. To exclude surface contamination, it is important that space between casing and pump pipe should be tightly sealed. For an open dug well, water-tight cover, preferably of concrete, should be used. Space between outside of curbing, or casing, and wall of the hole should be securely sealed. Casing of a shallow well should extend some distance below lowest level reached by water table when well is pumped during season in which

water table is normally at its lowest point. Well should be cased to the water-bearing stratum that is utilized. Chlorination of wells is now extensively practiced to eliminate and prevent contamination.—*C. C. Ruchhoft.*

Volumetric Determination of Sulphate. D. Nothall-Laurie. Analyst, 56: 665, 526–527, August, 1931. Boiler attendants, etc. can rapidly determine carbonate : sulphate ratio in boiler feed water; carbonate, by titration with standard acid, and sulphate, by titrating with acid sodium carbonate formed on shaking 100 cc. of water with a neutral suspension of barium carbonate (made by mixing equivalent amounts of barium chloride and sodium carbonate solutions, filtering, and neutralizing if necessary). Phenolphthalein is used as indicator; sample is neutralised with acid, shaken with barium carbonate suspension, and again titrated, slowly so that barium carbonate will not be acted upon. Cubic centimetres of 0.1 *N* acid multiplied by 96 equals parts per million of SO_4 or, by 142, equals parts per million of sodium sulphate.—*W. G. Carey.*

Llanelly Corporation Water Works. Anon. Water and Water Engineering, 33: 395, 517–524, October 20, 1931. Owing to water shortage, water scheme of Munitions Factory at Pembrey was purchased and adapted for use, thus saving £200,000 over competing projects. Watershed of Gwendraeth Fach river above intake is 32 square miles: water, diverted by weir, is roughly screened, gravitates 5½ miles, to balancing reservoir, is screened through two sets of wire mesh screens, 100 and 400 per inch respectively, and is then pumped by turbine pumps 8½ miles to existing reservoirs. Works etc. are described and illustrated.—*W. G. Carey.*

Corrosion of Metals. Anon. Water and Water Engineering, 33: 395, 513, October 20, 1931. German experience shows that fresh water is corrosive in water cooling of Diesel engine pistons, especially when aërated to minimise water hammer, corrosion being severe because of high rate of pumping and variations in velocity of flow by reversal of movement at every stroke. Bronze tubes are rapidly grooved, chromium and nickel plating are unsuccessful, but stainless steel is great improvement. With sea water pumps, manganese bronze is corroded, but stainless steel containing 14 percent chromium gives good service except when in contact with copper or bronze, or when running in leather packing, or when unfavourable conditions of aëration obtain.—*W. G. Carey.*

Lead in Potable Water. Anon. Water and Water Engineering, 33: 395, 512–513, October 20, 1931. Lead dissolved in water is of more frequent occurrence than generally supposed according to German researches. Acid reaction and dissolved oxygen are necessary and free carbon dioxide increases dissolution. If water is low in acidity, lead hydroxide is formed; if carbon dioxide is high, lead bicarbonate is also formed and is very soluble. Constant use of water containing only 0.5 milligrams per litre of lead is considered injurious to health and most fresh waters contain sufficient oxygen and carbon dioxide to cause this amount to be exceeded. Addition of lime to neutralise carbon dioxide is a sufficient preventive measure.—*W. G. Carey.*

Manufacture of Asbestos-Cement Pipes. Anon. Water and Water Engineering, 33: 394, 484–486, September 21, 1931. Illustrated description of the making of pressure pipes for water from asbestos-portland cement slurry which is fed in a thin dried film on to a polished steel mandrel and compressed by rollers. Pipes of 40 inches diameter and 13 feet long are made. Illustrations of sleeve and rubber ring joints and of long sleeve detachable joints are given.—*W. G. Carey.*

Hydrographical Survey of River Tees (England). Anon. Water and Water Engineering, 33: 394, 480–481, September 21, 1931. Survey included freshwater observations, calculations of fresh water discharge, current measurements in tidal estuary, movement of water towards sea, water levels and tide times, and deposition of silt. The Tees is subject to sewage and industrial pollution and purpose of investigation was to determine permissible pollution load which a river can carry without retarding self-purification, which is found to depend on volume of discharge, velocity of flow, and gradient of bed. Current strengths and water volumes moving upwards and downwards were measured by current meters in which velocities were registered by electric contact and telephone receiver. There is considerable difference between surface and deeper waters and at certain times the flood is running upstream below the surface while the ebb is running on the surface, due to difference in density between fresh and salt water.—*W. G. Carey.*

New Reservoirs at Godalming (England). Anon. Water and Water Engineering, 33: 394, 467–470, September 21, 1931. Of two reservoirs recently constructed of reinforced concrete, one, subject to considerable upward water pressure, has walls and roof of greater thickness than is usual and has dished floor with slabs 12 inches thick, walls being 8 inches thick and roof columns spaced at 13 feet centres. On roof are mixing chamber and chlorinating tank, former having baffle walls and weirs to retard flow of water which remains for 30 minute in the chamber. Reservoir is covered with earth to depth of 4 feet 6 inches. Second reservoir is lighter in design and has special system of ventilation and circulation which had to be unnoticeable to the public. Numerous small concrete vent chambers were constructed on roof, from which pipes are laid to discharge at inconspicuous points behind trees and are fitted with cowled ventilators.—*W. G. Carey.*

Sodium Aluminate in Modern Water Treatment. R. B. Beal and S. Stevens. Chemistry and Industry, 50: 34, 307–313 T, August 21, 1931. Limitations of lime-soda softening have been largely removed by use of sodium aluminate; water can be softened some two degrees [28.5 p.p.m.] more, because magnesium aluminate readily forms as flocculent precipitate, less soluble than magnesium hydroxide. Aluminate treatment is therefore specially suitable for waters high in magnesium, the hazard of corrosive magnesium chloride being eliminated. Reduction in cost of chemical is possible, for aluminate itself softens and lime requirement is further materially reduced due to suppression of interference by colloidal organic matter. Figures are given showing net saving in chemicals of nearly 3 cents per 1000 gallons. Speed of

precipitation is increased in both hot and cold processes, with consequent reduction of settling space and elimination of after precipitation. Where with lime and soda alone 45 hours were necessary, with sodium aluminate addition reaction is complete in 1 hour. Sedimentation and clarification become more efficient and graphs are given showing that filter runs are twice as long. Silica, one of the worst scale-forming substances, combines with sodium aluminate to form insoluble zeolite and is removed. For internal boiler treatment, solutions of sodium aluminate containing stabilizing proportions of caustic soda have proved to be powerful coagulants and, owing to large-sized particles formed, to diminish foaming tendency. For clarification and color removal without softening, sodium aluminate added to alum improves floc growth, reduces alum dosage, and gives better absorption of impurities, thus reducing chlorine requirement, as much in one case reported as 25 percent. Coagulation may be effected at higher pH values, while alkalinity of sodium aluminate tends to correct the more acid waters and reduce residual alumina. For removal of oil from condensate, sodium aluminate is superior to soda ash since it carries both alkalinity and alumina; it has been found to remove quantities as low as 0.1 grain of oil per gallon [1.4 p.p.m.].—*W. G. Carey.*

Recent Developments in Corrosion Prevention of Ferrous Metals. V. V. Kendall and F. N. Speller. Water and Water Engineering, 33: 395, 515–516, October 20, 1931. Principal developments in recent corrosion research are reviewed. Water supplies require special treatment to prevent corrosion; many become more corrosive as result of treatment which reduces their ability to form protective coatings on metal. For saline and mine waters and chemical solutions, portland cement protection has proved effective. Rust, or carbonate, accumulations may be removed by hydrochloric acid plus an inhibitor, or by steam, or other mechanical means; protection is then given by specially resistant portland cement applied by compressed air. In boiler embrittlement, attack is due to sodium hydroxide; sodium sulphate retards, or stops, this action and phosphates, tannates, chromates, nitrates, and acetates have similar effect.—*W. G. Carey.*

Protection of Metals by Metallic Films. E. S. Hedges. Chemistry and Industry, 50: 38, 768–772, September 18, 1931. Protection of metals, particularly iron, from corrosion, including electro-chemical and mechanical means, is discussed. Hot dipping in zinc, tin, and lead; electroplating with zinc, copper, nickel, chromium, and cadmium; metal spraying; and cementation, including sherardizing, chromizing, and calorizing, are all described.—*W. G. Carey.*

Effect of Dissolved Aluminium Salts on the Softening Power of Base Exchange Materials. B. A. Adams. Water and Water Engineering, 33: 394, 487–488, September 21, 1931. Solutions of aluminium sulphate in distilled water were passed through tubes containing synthetic and natural zeolites; the zeolites were treated with salt solution and their softening capacity to tap water determined. Results show that aluminium cations may be partially removed from solution by zeolites, irreversibly in case of synthetic material, so that

aluminium cannot be displaced from zeolite complex by treatment with sodium chloride and softening power, consequently, is ultimately destroyed. Natural zeolite retains permanently only a certain definite amount of aluminium; anything over that which it absorbs, it yields up again to salt solution and softening capacity is reduced by 43 percent only. Excessive amounts of cations and anions in natural waters do not prevent the absorption of aluminium cations. Sodium silicate restores the base-exchange properties of aluminium-contaminated material.—*W. G. Carey.*

Effect of Dissolved Manganese Salts on the Softening Power of Base-Exchange Materials. B. A. Adams. Water and Water Engineering, 33: 395, 533–535, October 20, 1931. Solutions of manganese salts in distilled and in tap water were passed through glass tubes containing synthetic and natural zeolites; manganese was determined in the effluent, zeolites regenerated with salt and their softening capacity redetermined. Manganese ions are removed and definite quantities are retained by zeolites before amount equivalent to that subsequently absorbed is removed by 5 percent salt solution, although by prolonged treatment with salt all the manganese can be removed. In slightly acid solutions little or no deposition of manganese hydroxide occurs, but in alkaline solutions hydroxide may be deposited, more readily when manganese is present as bicarbonate. Each of these factors effects a reduction in softening power of zeolites, reduction being more pronounced with synthetic than with natural zeolite. Excessive amounts of cations in natural water do not prevent absorption of manganese.—*W. G. Carey.*

The Hartford Filtration System. W. A. Genter. Water Works Eng., 84: 21, 1489, October 21, 1931. Hartford, Conn. obtained their new supply from Nepaug reservoir. New slow sand filter plant includes mixing chamber, fountain aërator, eight half-acre filter beds, and 6-m.g. filtered water basin. Mixing chamber is used to mix together old and new supplies. Filtering material consists of 12 inches of gravel overlying under-drainage system and three feet of sand on top of gravel. Sand has effective size of 0.29 mm. and uniformity coefficient of 2.0. Hydroelectric plant was built to furnish power necessary to operate filters. Plant operates under 45-foot head, taking water from one of two reservoirs no longer used for supply purposes. Spring and fall overturn periods in reservoirs have tendency to shorten filter runs. Aërator is shut off during cold weather. There are normally between 5 and 6 feet of water over sand in each bed. When the loss of head approaches 5 feet, beds are raked: after 5 rakings they are washed. Raking takes bed out of service for 24 hours. Present washing equipment, consisting of battery of four Nichols sand washers, is permanently housed on top of old filter beds, adjacent to sand court. When depth of sand has been reduced to 20 inches, it is replaced. Average cost of filtering water during 1930 was $3.03 per mg. Cost of washing sand was $0.74 per cubic yard and cost of resanding, $0.30.—*Lewis V. Carpenter.*

Geological Information on the Proposed Dam Site for the Aqueduct of Santiago de Cuba. E. I. Montoulieu. Revista de la Sociedad Cubana de In-

genieres, 23: 2, 92–106, March–April 1931. Seventeen holes spaced 40 meters apart were drilled to left of the Rio Cauto at proposed dam site and 13 holes, to the right. Seven of the holes fell within site of proposed dam. Average percentage of cuttings recovered was 67.24 percent. Volcanic breccia dominates, with occurrences of diorite, felsite, and basalt. The drill holes did not extend deep enough to determine strata underlying the breccia, dip of which is 30 degrees to the north. Maximum depth drilled was 87.70 meters, and total length of drillings was 1126.23 meters.—*J. F. Pierce.*

NEW BOOKS

Biological Chemistry and Physics of Sea Water. HARVEY, H. W. University Press, Cambridge, 1928, 208 pp. 10s. 6d. net. This volume in Cambridge Comparative Physiology series deals with physical and chemical conditions of the sea which affect and control plant and animal life and with the changes in these conditions with place and time. Brief history is given of investigations by expeditions and by Marine Biological Stations, followed by short outline of main types of marine plants and animals and their requirements for growth. Account is then given of chemical constituents of sea water, including discussion of hydrogen-ion concentration and its biological effects. Chapters are also devoted to movements, temperature, colour, and illumination of the sea. Final chapter deals with principles of productivity which emerge from present knowledge of these physical and chemical conditions, and with factors which give rise to differences in density of population between shallow and deep ocean areas, between areas of similar depth in different latitudes, and in same area from time to time. Each chapter is accompanied by bibliography and index is provided.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Journal of the Pennsylvania Water Works Operators' Association. 3: 99 pp., 1931. **Trouble Hour Papers.** 10–22. G. R. TAYLOR. Worms in service pipes temporarily disappeared after flushing. In one case it became necessary to renew the service pipe. Pond lilies in open storage reservoir were killed by applying copper sulphate over the mud surface after drawing the reservoir. Bats in screen chamber superstructure were killed by injecting chlorine gas into the enclosure. E. C. TRAX. Bad taste in water was due to mine water entering wells through fault in the rock strata. F. H. KNUTH. Chlorine ice was prevented (1) by tapping into the water heating system and installing a coil or heat transformer; (2) by hanging an electric bulb, fitted with a cone, over the jar; or (3) by passing exhaust water from steam heater around jar. E. C. GOEHRING. Inspection trips through purification plant by students, clubs, and church societies minimized complaints from consumers. J. V. CANNEN. Phenol tastes removed by introducing ammonia and chlorine in the ratio of 1:1. H. J. KRUM. Turbidity in filtered water to an extent of 1 p.p.m. objectionable. H. M. SEARFAUSS. Copper sulphate applied in suction well improved condition of rapid sand filters. **The New Filter Plant at Erie, Pa.: Basis of Design.** J. T. CAMPBELL. 23–27. Gravity intake line is

of 72-inch riveted steel pipe dipped in hot bath of bituminous coating. Bids on steel pipe were 20 percent lower than for cast iron, or for concrete. Low-service pumping units are operated by remote control from high-service pump station. Mixing chambers are 20 feet square by 21 feet deep: horizontal revolving paddles give water velocity of 0.6 foot per second: retention period at 32 m.g.d. rate is twenty minutes. Retention period of settling basins at same rate is three hours: water is given a free path, without baffles, or other constraints. Filters, in two-million-gallon units, are provided with false bottom 20 inches deep. Copper screen holds gravel in place. **Filter Washing: Theory and Application of Sand Expansion as an Index.** Roberts Hulbert. 28–43. Expansion of sand bed during wash, or its increase in volume, is the natural index of washing intensity. Size, shape, and specific gravity of sand grains and velocity and viscosity of wash water are the important fundamentals in the equation of sand suspension. Sand grains of uniform size, spherical in shape, and of same specific gravity, will become suspended, or "float," in upward flowing wash water of a given temperature, at a certain definite velocity of flow which will be the same for each grain. In colder water, this velocity will be less than in warmer. Wash velocity must also be varied according to the size of sand, larger particles requiring a disproportionately higher velocity to float them. Sand expansion is best expressed in terms of percentage of depth. Sand particles tend to become more and more spherical and lighter as gelatinous coating accumulates. To determine sand expansion. (1) Measure elevation of settled sand surface. Convenient measuring rod can be made by attaching flat block of wood, or metal plate, to length of half-inch pipe graduated in inches and tenths. Rest plate upon sand surface and read off its elevation with relation to top surface of filter wall. (2) When washing filter, rest plate upon surface of gravel and note levation. Difference between the two readings is depth of sand. (3) Height of sand suspension is measured by another graduated rod with hook at lower end. Upon this hook is adjusted in upright position, a six-volt 50-c.p. electric bulb so that its top surface coincides with zero on the rod scale. When washing, lower hook-guage into water until light is just barely obscured. Difference between gravel elevation and that of surface of expanded sand gives the thickness of the bed while in suspension during wash. The clearance between sand surface and bottom of wash-water troughs should be greater than 50 percent of sand depth. **The Ammonia-Chlorine Treatment of Water and Its Development.** J. F. T. Berliner and A. E. Howe. 44–52. Ammonia-chlorine treatment may be used to prevent algal and slime growths in swimming pools, city water mains, and condenser waters for power plants, as well as for taste prevention. It has possibilities for wash waters used in preparation and packaging of foods and in cleaning of milk bottles and cans; also for preventing slime growth in pulp and ground wood manufacture. Ammonia treated with chlorine forms chloramines which are highly soluble and very stable, are extremely weak oxidizing agents, and retain their bactericidal effectiveness under exposure to direct sunlight. The process is not a "cure all" for all taste difficulties. For taste and odor control, it is essential that ammonia be introduced prior to chlorination. For better sterilization, this is not imperative. Anhydrous ammonia gas is introduced into water supply in a manner analogous to that employed

with chlorine. Correct location of point of introduction is important. Average ratio of ammonia to chlorine now being employed is about 2:3. Same apparatus and color standards can be used for testing for chlorine, or for ammonia-chlorine, except when nitrites are present. **Influences of Soils, Rocks and Minerals Upon The Potability of Water.** J. J. SHANK. 53–60. A non-technical description. Potability from chemical standpoint depends upon the type of stratum from which water is obtained, plus character of original flow, plus effects of all the various strata and soil combinations through which supply has penetrated. **Drought Problems.** H. E. MOSES. Review of 1930 drought effects in Pennsylvania. Changing characteristics of river water as flow decreased caused trouble to some plants. Tree growth affected. Five field mobile laboratories were used to check emergency supplies. In 48 counties 125 communities were obliged to use auxiliary or emergency supplies. In 41 counties there were 96 places which had to resort to emergency measures. No typhoid fever outbreak could be attributed to any normal or emergency public water supply. **The Water Works Man and the Public.** H. B. RICHARDS. 78–83. **The Filtration of a Stored Water.** J. Z. COLUMBIA. 84–88. Langeloth, Pa., water supply is a combination of several ground waters with surface water. Turbidity varies from 3 to 3000 p.p.m., with average of 23. With high turbidities, filter effluent has earthy tastes and odors. Frequent washing of filters reduced tastes slightly. It was noted that the presence of microörganisms depended upon atmospheric temperature, increasing with approach of warm summer days. Copper sulphate added to reservoir produced favorable results in sixty hours. Subsequent applications were made according to intensity of growth of organisms. **Lime-Soda-Ash Process of Water Softening.** F. W. BOUSON. 89–94. Raw water supply of South Pittsburgh, Pa., Water Company is taken from Monongahela river. Hardness is all present as sulphate, necessitating use of soda ash. Author describes softening process, control of which is based on non-carbonate hardness of water as it reaches the softening plant. Split treatment is used to accomplish the complete carbonation of softened water. After aëration, water is conducted to four mechanical mixing tanks, thence to settling tank equipped with continuous sludge removal mechanism. From this clarifier, the softened water flows through flume into basin where the alkalinity, present as normal carbonate, is changed to bicarbonate by carbonation, and thence to the filters.—*J. F. Pierce.*

Engineering. (Our Debt to Greece and Rome Series.) ALEXANDER PURVES GEST. New York; Longmans, Green & Co. Cloth; 5 x 7 inches. Pp. 221. $2. Reviewed in Eng. News-Rec., 105: 622, October 16, 1930.—*R. E. Thompson.*

Estimating Construction Costs. G. UNDERWOOD. New York and London; McGraw-Hill Book Co. Flexible; 6 x 9 inches; pp. 620. $6. Reviewed in Eng. News-Rec., 105: 622, October 16, 1930.—*R. E. Thompson.*

Federal Limitations upon Municipal Ordinance-Making Power. HARVEY WALKER. Ohio State University Press. Cloth; 6 x 9 inches; pp. 207. $3. Reviewed in Eng. News-Rec., 105: 624, October 16, 1930.—*R. E. Thompson.*

Der Ruhrverband. K. Imhoff. Berlin W. 8, Germany; Carl Heymanns. Stiff paper; 8 x 12 inches; pp. 62. Reviewed in Eng. News-Rec., 105: 624, October 16, 1930.—*R. E. Thompson.*

The Measurement of Hydrogen-Ion Concentration. Julius Grant. London, New York, and Toronto; Longmans, Green & Co. Cloth; 6 x 9 inches; pp. 159. $3.75. Reviewed by J. R. Baylis in Eng. News-Rec., 105: 817, November 20, 1930.—*R. E. Thompson.*

Essai d'Hydrogeologie. Ed. Imbeaux. Paris; Dunod, 92 Rue Bonaparte (VI). Paper; 8 x 11 inches; pp. 678. 284 francs. Reviewed by I. Gutmann in Eng. News-Rec., 105: 818, November 20, 1930.—*R. E. Thompson.*

Life Expectancy of Physical Property: Based on Mortality Laws. Edwin B. Kurtz. New York; The Ronald Press Co. Cloth; 6 x 9 inches; pp. 205. $6. Reviewed in Eng. News-Rec., 105: 815, November 20, 1930, by J. H. Gregory.—*R. E. Thompson.*

Appraisers' and Assessors' Manual. W. L. Prouty, Clem. W. Collins and Frank H. Prouty. New York and London: McGraw-Hill Book Co. Cloth; 6 x 9 inches; pp. 500. $5. Reviewed in Eng. News-Rec., 106: 120, January 15, 1931.—*R. E. Thompson.*

Heat Loss Analysis. The Key to Economic Boiler Operation. E. A. Euhling. London: McGraw-Hill Publishing Co., Ltd. 12s. 6d., net. From Chem. Abst., 24: 2214, May 10, 1930.—*R. E. Thompson.*

The Corrosion of Metals. Wilh. Palmaer. Stockholm: Svenska Bokhandelscentralen A.-B. 347 pp. Kr. 20. Reviewed in J. Inst. Metals, 42: 730, 1929. From Chem. Abst., 24: 2414, May 20, 1930.—*R. E. Thompson.*

Oxy-Acetylene Welding and Cutting, A Course of Instruction. Stuart Plumley. Minneapolis: Univ. Printing Co. 302 pp. $7.50. From Chem. Abst., 24: 2414, May 20, 1930.—*R. E. Thompson.*

The Chemistry and Bacteriology of Public Health. C. L. Dunn and D. D. Pandya. Calcutta, India: Butterworth & Co. 412 pp. Reviewed in Indian Med. Gazette, 65: 232, 1930. From Chem. Abst., 24: 3306, July 10, 1930.—*R. E. Thompson.*

Die physikalische Chemie der Kesselsteinbildung und ihrer Verhütung. R. Stumper. Heft. 3 of "Sammlung chemischer und chemisch-technischer Vorträge." Stuttgart: F. Enke. 51 pp. M. 4.80. Reviewed in Chem. News, 140: 363, 1930. From Chem. Abst., 24: 3847, August 10, 1930.—*R. E. Thompson.*

The Welding Industry. Harold S. Card. Chicago: The Welding Engineer Publishing Co. 128 pp. From Chem. Abst., 24: 3980, August 20, 1930.—*R. E. Thompson.*

The Modern Dowser: A Guide to the Use of the Divining Rod and Pendulum. HENRY DE FRANCE. London: G. Bell & Sons, Ltd. Cloth; 5 x 8 in.; pp. 135. 3s. 6d. net. Reviewed in Eng. News-Rec., **107**: 819, November 19, 1931, by ABEL WOLMAN.—*R. E. Thompson.*

Handbuch der Wünschelrute: Geschichte, Wissenschaft, Anwendung. CARL VON KLINCKOWSTROEM und RUDOLF Freiherr VON MALTZAHN. Munich: R. Oldenbourg. Linen; 6 x 9 in.; pp. 321. 18 marks, or 16 marks in paper covers. Reviewed in Eng. News-Rec., **107**: 819, November 19, 1931, by ABEL WOLMAN.—*R. E. Thompson.*

Archiv zur Klärung der Wünschelrutenfrage: Organ des Verbandes zur Klärung der Wünschelrutenfrage E. V. CARL VON KLINCKOWSTROEM, RUDOLF VON MALTZAHN und EDWIN MARQUARDT. Vol. 1, No. 1, July, 1931. Munich: R. Oldenbourg. Paper; 7 x 10 in.; pp. 72. 4 marks for two issues per year; single copies, 2.5 marks. Reviewed in Eng. News-Rec., **107**: 819, November 19, 1931, by ABEL WOLMAN.—*R. E. Thompson.*

Life Characteristics of Physical Property. ROBLEY WINFREY and EDWIN B. KURTZ. Bulletin **103**, Iowa Engineering Experiment Station. Ames, Iowa: Iowa State College. Paper; 6 x 9 in.; pp. 143. Reviewed in Eng. News-Rec. **107**: 819, November 19, 1931, by JOHN H. GREGORY.—*R. E. Thompson.*

The Surface Waters of Michigan. Hydrology and Qualitative Characteristics and Purification for Public Use. ROBERT L. MCNAMEE. Engineering Research Bulletin No. **16**, University of Michigan, June, 1930. Prepared in partial fulfilment of the requirements for the degree of Civil Engineer in the University of Michigan, this remarkable work reflects unusual credit upon its author and upon the institution, because of its excellent quality and the amount of data presented. It is of broader scope than is indicated by its title. Only Parts II and III, covering 240 pages, are devoted to data applicable to the surface waters of Michigan alone. Parts I and IV contain matters of general interest so broad in their application as to make the book of general use for reference and as a textbook.

Part I on "The Fundamental Requirements of a Public Water Supply" contains information on rates of water consumption in Michigan cities and on standards of quality for municipal water supplies. A tabulated summary of proposed standards of quality might be adopted more widely than within the boundaries of the state of Michigan alone. The standards cover physical, chemical, and bacteriological content, and fix acceptable limits therefor.

Practically every conceivable method for the purification of surface waters is mentioned in Part IV under the heading "The Purification of Michigan Surface Waters for Public Use." The timeliness of the information presented is indicated by a paragraph on the use of chemicals in water purification. It is stated that: "Chemicals in water purification are becoming more and more widely used, not alone due to the number of purification plants in service, but also to the wider application of this method of water treatment. The wider usage of chemicals has resulted in the development of improved methods for

handling, storing, and feeding them, and in better designed and better constructed devices for securing their thorough and complete reaction with the water." The loads placed on purification processes by industrial wastes and other forms of pollution commonly encountered in Michigan are discussed together with remedial measures of nuisance abatement and the treatment of industrial wastes.

Principal purposes of water purification in Michigan include bacterial removal, clarification, softening, removal of iron and manganese, destruction of algae, and removal of disagreeable tastes and odors. Methods for the accomplishment of each of these purposes are described; the greatest space being devoted to the removal of disagreeable tastes and odors. The fundamental causes of disagreeable tastes and odors discussed are industrial wastes, algae, chlorine, dissolved gases, iron compounds, calcium sulphate, and miscellaneous and unknown causes. Methods of overcoming each of these causes are described.

Water purification practice in Michigan is treated in terms of such general nature that the experience and conclusions may be of use to water works men in other states. For example; it is stated: "The more important and common structures, devices, and equipment utilized in water purification plants are included in one or another of the following classifications: screening devices, aërators, chemical treatment devices, sedimentation equipment, filters, and sterilization equipment. Some of the more important fundamental principles of the design and operation of these plant elements are discussed in the following pages." The section terminates in a large table giving design and operating data on 27 municipal rapid sand filtration plants in Michigan.

Information in the main portion of the work is devoted to the primary and secondary watersheds of the state, including 9 basins and 46 river systems. Data are given on their climate, topography, surface geology, lakes and swamps, impounding reservoirs, sewers and sewage, population, industrial wastes, culture, drainage, stream flow, and location. Much of the material is given in tabulated form, followed by a summary and some of the information is also shown on the various folding maps included in Part II.

The book is bound in paper and is moderately well printed, with a few typographical errors. It contains 320 pages, 6 by 9 inches, 9 folding maps 14 by 9 inches, two large folding tables, and one large inserted map. It can be obtained through the Department of Engineering Research of the University of Michigan at Ann Arbor for $1.50—*H. E. Babbitt.*

handling, storing, and testing them, and in better designed and better constructed devices for applying their chemicals, and complete reaction with the water. The tests placed on chlorination processes by industrial wastes and other forms of pollution commonly encountered in Michigan are discussed together with principal measures of nuisance abatement and the treatment of industrial wastes.

Principal purposes of water purification in Michigan include bacterial removal, clarification, softening, removal of iron and manganese, destruction of algae, and removal of objectionable tastes and odors. Methods for the accomplishment of each of these purposes are described, the greatest space being devoted to the removal of objectionable tastes and odors. The fundamental causes of objectionable tastes and odors discussed are industrial wastes, algae, chlorine, dissolved gases, iron compounds, sulfur compounds, and miscellaneous and unknown causes. Methods of overcoming each of these causes are described.

Water purification practice in Michigan is treated in terms of such general information that the experience and conclusions may be of use in water works situations elsewhere. For example, it is shown that the more important and common structures, devices and equipment utilized in water purification plants are included in one or another of the following classifications: screening devices, aerators, chemical treatment devices, sedimentation equipment, filters, and sterilization equipment. Some of the more important fundamental principles of the design and operation of these plant elements are discussed in the following pages. The section terminates in a large table giving design and operating data on 27 municipal rapid sand filtration plants in Michigan.

Information in the main body of the work is devoted to the primary and secondary watersheds of the state, including 9 basins and 48 river systems. Data are given on their climate, topographic surface geology, lakes and streams, important industries, sources and sewage, population, industrial wastes, factors affecting stream flow, and location. Much of the material is given in tabulated form, followed by a summary, and some of the information is also shown on the various outline maps in Part II.

The book is bound in board and is moderately well printed, with a good typographical format. It contains 340 pages, 9 by 12 inches, 5 folding maps 14 by 8 inches, 80 large folding tables and one large colored map. It can be obtained through the Department of Engineering Research of the University of Michigan at Ann Arbor for $5.00.—H. E. BABBITT.

ERRATA

Vol. 24, No. 4, April: The Discussion on Steel Pipe, pp. 575–577, was presented by Mr. Philip Burgess, Engineer, Columbus, Ohio.